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THE EFFECT OF LONG-TERM THERAPEUTICS, PROPHYLAXIS AND SCREENING--ETC(11)  
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ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

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### The Effect of Long-Term Therapeutics, Prophylaxis and Screening Techniques on Aircrew Medical Standards

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THE EFFECT OF LONG-TERM THERAPEUTICS, PROPHYLAXIS AND  
SCREENING TECHNIQUES ON AIRCREW MEDICAL STANDARDS

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by

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### INTRODUCTION

During the AGARD Aerospace Medical Panel Specialists Meeting in Lisbon in October 1979 the "Operational Roles, Aircrew Systems and Human Factors in High Performance Aircraft" were discussed, particularly in relation to the F16, Mirage 2000 and Tornado aircraft. The much enhanced performance of these aircraft, and the apparent stresses which new operational techniques would impose, prompted the Aerospace Medical Panel to consider the effects of such changes on aircrew selection and medical standards.

Two developments had taken place concurrently, and each, in differing ways, would influence such consideration.

(a) Advanced aircraft had been introduced which placed a much increased stress on aircrew who would be subjected to the high physical stress loads of sustained high 'g' manoeuvres, vibration, high noise levels and heat stress, and who would be required to produce a constant, high degree of concentration with little or no margin for error. Would an increased degree of aircrew fitness be necessary? Was there a need for special selection of aircrew to fly these aircraft?

(b) The diagnosis of certain diseases had, to date, resulted in the aircrew concerned being declared permanently, unfit to fly. Modern methods of treatment, however, now made it possible to consider the return of these aircrew to flying duties. The introduction of beta-blockade in the treatment of hypertension, surgical intervention to relieve coronary artery insufficiency and a better understanding of the stress of flying are examples of such improvements. Under what conditions may aircrew with diseases which require long-term therapy continue to fly? What limitations must be applied in such cases?

To find answers to these questions "The Effects of Long-term Therapeutics, Prophylaxis and Screening Techniques of Aircrew Medical Standards" was proposed as the subject for this meeting. The 18 papers received highlighted a particular interest in two specific areas, and the session could conveniently be divided into two parts, each lasting one day. Part I contains papers on medical standards, screening and selection of aircrew, while papers on the epidemiology and management of specific conditions comprise Part II of the session. The meeting was held at the Defence and Civil Institute of Environmental Medicine, Toronto, Canada on 18 and 19 September 1980.

### DISCUSSION

Epidemiological survey techniques, both retrospective and prospective are used by many of the authors to establish a base-line from which standards can be derived. Dr K Myhre in the opening pages of Part I (1), described a prospective study, started in 1980, which will compare the cardiovascular capacity of pilots with their physical fitness. Measurements will be made at routine periodic medical examinations. Although the number in this study is limited, and highly selected at medical examination on entry to military service, the study will be carried out under controlled conditions such that trends may assume greater significance. The paper highlights the importance of preventive techniques in the medical supervision of aircrew.

Dr H T Andersson (2) reported a five year study of the physical fitness of young aircrew compared with their physical activity and dietary intake. Fitness was assessed using the maximal aerobic power (VO2 max.) and compared with recorded organised physical activity and diet. The compulsory physical activity undertaken during early military training was shown to produce a significant increase in fitness, subsequently lost when physical activity became voluntary, and when dietary habits changed.

Dr J E Whinnery (3) described a study to assess measurable criteria associated with +Gz tolerance. A group of aircrew undergoing aeromedical assessment for subtle cardiovascular abnormalities were subjected to a centrifuge acceleration stress test and the results compared with the standard treadmill stress test and clinical evaluation normally carried out. Comparison was also made with a group of healthy volunteer subjects. Anti-G suits were worn for the centrifuge test and the maximum exposure used was +7Gz.

The study has confirmed that +Gz tolerance is not related to aerobic capacity and that overall the higher +Gz tolerance is demonstrated by the older, shorter, heavier and more experienced aircrew who tend to have a higher than average blood pressure. Many of these factors, however, have an associated increased risk of cardiovascular disease. A lower +Gz tolerance is shown by the tall, thin and less experienced subjects. The increased incidence of cardiac dysrhythmia associated with increased exposure to +Gz was shown, and the significance of these dysrhythmias as a possible measure of +Gz tolerance was discussed. The need to identify +Gz induced, medically significant dysrhythmia in aircrew selected to fly the new generation of high-performance aircraft was stressed.

Dr R Auffret ( 4 ) described the use of a centrifuge stress test as an adjunct to the routine clinical investigation of aircrew. During the past three years 27 aircrew, including student pilots, had been investigated and the cases included pneumothorax, acceleration induced airsickness and cardiac abnormalities. During the test the ECG, heart rate, blood pressure, cardiac output and peripheral visual fields were assessed. The test was considered a valuable assessment but was unlikely to be introduced routinely because of the workload involved. Of particular interest was the assessment of a hypertensive pilot, treated with beta-blockade, whose +Gz tolerance was found to be unaltered up to +5Gz, and for whom a medical waiver for one year was granted.

The stringent medical examination and acceptance criteria employed to select subjects for experimental acceleration and impact studies were outlined by Dr B A Heaton ( 5 ). The examination is designed to ensure that subjects selected are free of any predisposing conditions which might lead to injury.

An analysis of the medical evaluation of all unsuccessful candidates during the 2 year period 1977-1979 has been carried out. Of all candidates rejected on medical grounds 93% were found to have radiological spinal abnormalities. This represented 31% of the total applicants, who were asymptomatic and without past history of spinal problems.

The need for a similar screening procedure for aircrew subjected to high G stress and exposed to the risk of high ejection stress loads was discussed in this paper.

Dr M G P Fisher ( 6 ) gave a more general assessment of the problems associated with the management of unfit aircrew and highlighted the importance of the Flight Medical Officer (Flight Surgeon) in the assessment procedure. By virtue of his training and his close association with operational aircrew the Flight Medical Officer is well qualified to provide a risk assessment in the return of aircrew to flying status following medical treatment.

There are many cases, however, in which a risk assessment cannot be closely defined. For example, the prognosis in certain conditions may be uncertain, or the effect of drugs on pilot performance cannot be accurately assessed. Several examples have been given by Dr Fisher which indicate the need for continued research.

The risks associated with poor dark adaptation in a military environment were discussed by Dr H Zwick ( 7 ). Because no simple screening test is available many military personnel are unaware of their inability to 'see' at night.

To date dark adaptometers have been complex optical devices, not readily transportable and unsuitable for screening purposes. The paper described the development, using new technology, of a screening dark adaptometer and its validation in the laboratory.

With an estimated 15% of the 'normal' population subject to some difficulty in altering light sensitivity in darkness the LAIR Dark Adaptometer should be a valuable addition to a screening programme.

A screening programme for noise-induced hearing loss in military personnel was described by Dr H M Borchgrevink ( 8 ). The programme is in accord with programmes being set up by many NATO countries and concentrates on the establishment of risk criteria for noise exposure, and routine screening employing pure-tone audiometry and speech assessment, of all personnel at risk.

Visual acuity is presently assessed using standard test cards, normally high contrast black letters on a white background. The significance of contrast sensitivity in the performance of many pilot tasks in military aviation is now becoming more widely recognised. Dr A P Ginsburg ( 9 ) described the development of contrast sensitivity tests designed to reveal individual differences between subjects assessed as normal by present methods of assessment.

The importance of good contrast sensitivity in pilot skills such as target acquisition and identification was explained, and the collection of data which this research will facilitate will allow a critical assessment of current techniques and the development of future screening tests with a more functional application.

Airsickness continues to be a serious factor in the wastage rate of both student and trained aircrew. Through the years many treatment regimes have been employed with varying degrees of success. Dr D R Jones ( 10 ) described a new technique, introduced in 1979, which employs biofeedback relaxation techniques with physiological monitoring. He emphasised the importance of high motivation in aircrew selected for treatment, and the need for careful briefing of patients in the use of biofeedback equipment and relaxation techniques.

The treatment is based on the premise that symptoms of motion sickness are mediated by the autonomic nervous system and that voluntary control of the autonomic response can be employed to prevent or diminish the symptoms.

A success rate of 84% has been achieved in aircrew treated to date.

The problems of the rehabilitation and the return to flying status of aircrew suffering from stress related conditions continue to present a challenge to experts in this field. Dr R W Kemmler ( 11 ) reported the results of treatment of a group of 44 aircrew treated between 1973 and 1979 and, based on the conclusion reached in his review, proposed an assessment and treatment plan for future cases.

Since prevention is better than cure, the proposals include psychological selection testing to identify candidates liable to stress, an education programme to improve stress tolerance and the identification of high risk tasks so that supervisors and personnel in such posts are aware of the stress risk.

On the assumption that the number of human factor accidents can be reduced, and since stress is frequently an important factor in such accidents, continued research in this field is essential.

The aeromedical investigation of aircraft accidents has assumed greater significance in recent years. More complex and thorough examinations are carried out.

The use, or misuse, of drugs has become more prevalent and Dr J L McBurney (12) described a technique which has been developed to detect and determine the time of ingestion of diazepam; a technique which can be used in the investigation of aircraft accidents/incidents.

Part II of this session contained six papers, four dealing with the epidemiology and management of cases of cardiovascular abnormality and two dealing with the effect on aircrew performance of drugs used in conditions, including cardiovascular disease, which demand long-term therapy. It is hardly surprising that the focus should be on cardiovascular disease since this continues to be the dominant cause of loss of flying category on medical grounds. It is also a field in which considerable advances in treatment have been made, particularly in the treatment of hypertension, and yet these advances have brought with them significant difficulty in the assessment of fitness and the calculation of risk.

The calculation of risk and the application of this assessment was the basis of a paper submitted by Dr E Alnaes (13). He has reminded us of two facts, firstly that cardiovascular disease accounts for 65% of the medical causes of loss of flying status over the age of 35, and secondly, that cardiovascular risk factors are now well established.

Based on a large scale Scandinavian long-term study of urban populations he has been able to quantify the degree of risk of cardiovascular disease and has proposed a policy for the screening and management of aircrew. Screening will start with prospective aircrew at selection medical examination and continue throughout the service career of serving personnel at periodic medical examinations.

In otherwise asymptomatic aircrew the diagnosis of latent coronary artery disease, usually suspected following minor abnormalities in the electrocardiogram, normally depends on the results of standard treadmill tests. Dr M A Montgomery demonstrated in his paper (14) the value of computer enhanced Thallium-201 scintigraphy in confirming the disease, and he was also able to demonstrate that the proportion of false positive results obtained was significantly reduced, compared with the treadmill test. The introduction of this technique should reduce significantly the number of patients who require coronary angiography.

The decision to grant a waiver to aircrew to return to flying when certain types of cardiovascular disease are diagnosed is not one which is taken lightly, and the validation of that decision is achieved by careful follow-up over a prolonged period. Dr G B Madrakis (15) made this point in his report of the follow-up during a 10 year period of 39 pilots with a variety of cardiovascular abnormalities who had been retained on flying status.

The paper also showed that, for certain diseases a policy for treatment, a period of mandatory grounding and the conditions for return to flying status had been established. Significantly, none of the patients had shown any additional abnormality or cardiac event during the follow-up period.

Continuing on the subject of cardiovascular disease Dr C E Simpson presented the paper by Dr J N C Cooke (16) which dealt with the treatment of hypertension using beta-blockade. Hypertension has, for many years, been a disqualifying disease for a medical licence to fly; and the consequent wastage of highly-trained aircrew has given much cause for concern.

The paper discussed the assessment of hypertensive aircrew and the difficulties clinicians had in determining the most suitable treatment regime. The beneficial effects of beta-blockade were explained and the significance of the central effects and side effects of the various drugs available was discussed.

Investigations carried out to assess the importance of these effects with particular reference to flight safety were also described. A policy for limited employment in flying posts of aircrew successfully treated for hypertension was proposed in the concluding section of the paper.

Beta-blockade, although primarily used in the treatment of cardiovascular disease, is also efficacious in the treatment of anxiety. The central effects of some of the beta-blockading drugs are well known and Dr D Harms in his paper (17) commented upon the lack of consistent data on the effects of these drugs on aircrew performance.

The paper described work done to develop and prove a method of assessment using visual reaction time. The particular assessment of atenolol showed the significant decrease in central effects of the drug contrasted with the past experience gained using propranolol.

The final paper, presented by Dr W Nissen (18) highlighted the value of modern data storage techniques in the maintenance of medical records and the usefulness of such recording in statistical analysis.

Three conditions, hypertension, hyperlipoproteinaemia and euthyroid goitre have been examined to assess long-term therapy in aircrew. The survey has shown that this therapy, during the flying career of military aircrew, is necessary in relatively few cases and that, particularly in the case of cardiovascular disease, the identification of risk factors and the provision of sound medical advice and guidance is a more profitable approach.

## SUMMARY AND RECOMMENDATIONS

The questions which were posed prior to this meeting were based on a growing concern that advanced military aircraft had a performance potential which exceeded the physiological capabilities of the average pilot to such a degree that a highly selected cadre of pilots would be required to fly them.

The medical standards laid down for entry to aircrew training, and for retention on flying duties, have, in most NATO countries, remained unaltered for many years. In the past, in most Air Forces, there was no shortage of pilots and, if one became unfit, another fit pilot was available to ensure that squadrons remained fully manned. Medical fitness had little financial or manning implication. Today, training costs are high and medical fitness has assumed considerably more importance.

Whether or not the meeting was successful must depend upon the extent to which the following questions were answered.

1. Do aircrew need to be specifically selected to fly the new generation aircraft?

Considerable effort is being made to determine and quantify the risk factors involved. G-stress effects are being assessed, as are visual and hearing requirements. Ejection stress loads are being considered. Programmes to deal with the stress of flying and airsickness continue to be improved and developed. Further research will be required before any selection criteria can be established.

2. Bearing in mind the high cost of training, do the aircrew medical standards for entry and retention need to be revised?

Standards have stood the test of time and the emphasis has been directed primarily to the introduction and improvement of screening programmes to identify those at risk, if possible at the selection medical examination. It will take time to prove these techniques but the epidemiological studies and modern methods of data storage will benefit these programmes significantly.

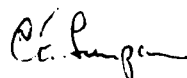
3. Can aircrew under long-term therapy for conditions such as hypertension continue to fly?

Experience and evidence from research is now making it possible to propose a return to limited flying in certain categories of disease, particularly hypertension treated with beta-blockade. The effect on pilot performance of such drugs is more difficult to quantify and the decision as to when to introduce beta-blockade in the treatment of aircrew continues to be a subject for debate.

The prime emphasis throughout the meeting centred on risk - both in flight safety terms and to the individual. Risk assessment was seen to have assumed much increased importance in research and in medical fitness to fly. While risk can be estimated as a result of medical research, the acceptability of that risk can only be assessed, in conjunction with all other risk factors in military aviation, by the Air Staffs.

Further research will be required and to obtain the most beneficial results the following recommendations are made.

1. Definitions and research protocols should be standardised.
2. To facilitate information exchange, data to be recorded should be standardised.
3. Aircrew performance assessment techniques, for use in the study of drug effects, should be improved and developed.



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# PHYSICAL FITNESS AND CARDIOVASCULAR CAPACITY - AN EPIDEMIOLOGICAL PROGRAM

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## Summary.

Recent results indicate that when a compulsory exercise program during initial flying and military training is changed to a voluntary regime the physical fitness of the subjects involved deteriorates, due to both weight increase and reduced maximal oxygen intake. Further we have reason to suspect that the high energy intake and relative sedate life style is continued for most of the subjects, except for those habitually engaged in physical activity. Consequently, we felt it was important to obtain a longitudinal survey of the way of living of all personnel with flying status in terms of diet, smoking and drinking habits and habitual physical activity, in addition to anthropometrical/physiological parameters such as weight, percentage of fat, maximal aerobic power, serum concentrations of triglycerides, total cholesterol and HDL cholesterol. This information is obtained from each subject during his periodical major medical examination at the Institute of Aviation Medicine, which is every sixth year when the subject is below 40 yrs of age, otherwise every third year. This program is discussed.

## Introduction.

It is generally assumed that low level of physical activity and the dietary and smoking habits of modern life contribute to the development of cardio-vascular diseases.

Recent results obtained by us in a population of military personnel indicate that when a compulsory exercise regime during initial flying and military training is changed to a voluntary one, the physical fitness of most of the subjects deteriorated. This decline was due to increased weight and reduced maximal  $O_2$  uptake. Moreover, we have recently had incidents of myocardial infarction among active pilots. Characteristically these patients were extremely sedentary, smoked excessively and their plasma lipoprotein concentrations were increased.

The connection between plasma lipoprotein concentration and coronary heart disease (CHD) is well established. There is good evidence that a negative correlation exists between serum HDL cholesterol levels and the possibility of developing CHD. Furthermore, both epidemiological and experimental evidence indicates that increased serum concentrations of LDL cholesterol and VLDL triglycerides are correlated to atherosclerosis (1).

Several factors may contribute in inducing changes of plasma lipid and lipoprotein concentrations. Increased levels of total cholesterol and triglycerides with age are reported (2, 3).

HDL cholesterol concentrations are positively correlated with intake of alcohol, while the reports concerning the relationship between HDL cholesterol and both smoking and obesity are conflicting (3). Furthermore, there is good evidence that physical exercise promote changes in the plasma lipoprotein pattern. Very active individual are reported to exhibit higher concentrations of HDL cholesterol and lower concentrations of total triglycerides, and LDL cholesterol than sedentary individuals of same sex and age (3).

## Program goal.

The program, which involves all Air Force personnel requiring medical classification, is aimed to obtain a survey of the habits of smoking, drinking and physical activity related to health parameters such as weight, body fat content, maximal aerobic power and serum concentrations of total cholesterol, HDL and LDL cholesterol and total triglycerides.

This program will make it possible to intervene if an individual pattern should develop unfavorably. Furthermore, it is of interest to compare the results of our pilot population with results obtained in an average Norwegian population. There will also be possible to perform multivariate analysis of the factors contributing to changed lipoprotein patterns.

## Program design.

The survey is presently connected to the major medical examination performed every sixth year on each individual below 40 years of age, otherwise every third year. This examination requires that the subjects appear at the Institute of Aviation Medicine where the tests of the present program are performed.

1. The height and weight of the subjects, dressed in shorts only, are measured to the nearest 1 cm and 100 g respectively.
2. The assessment of the body fat content is based on measurements of the thickness of 4 skinfolds on the right side of the body. The skinfold readings are performed at the biceps, triceps, subscapular and supra-iliac areas as described by Diurnin and Womersley (4), using the Harpenden skinfold calipers (British Indicator Ltd, St. Albans Herts). The constants in the regression equation used to estimate the body density, is selected according to the age of the subjects, and the body fat is estimated from the body density (4).
3. The maximal aerobic power is assessed indirectly according to the method of Astrand and Rhyming. (6,7). The procedure is standardized and the work is performed on an electromagnetically braked bicycle ergometer (Siemens-Elema 380R, Stockholm, Sweden).

Date  
 Name  
 Date of birth  
 Rank/Function

Select the most suitable alternative.

Smoking habits

Never smoked ☐ . Stopped smoking ( 6 months) ☐ . Number of cigarettes each day: 0-10 ☐ , 10-20 ☐ , > 20 ☐ .

Physical activity

More than 30 min continuous physical exercise which produce increased heart rate is interpreted as training. How often do you train: Never ☐ . 1-2 times monthly ☐ . 1-2 times weekly ☐ . 2-3 times weekly ☐ . 4-6 times weekly ☐ .  
 Type of activity .....

Diet

Alcohol: Two bottles of lager beer produce an alcohol concentration in the blood of about 0,05%. Do you have a blood concentration of this size more than once a week ☐ , once a week ☐ , less than once a week ☐ , never ☐ .

Coffee/tea: How much do you drink each day? 0-3 cups ☐ > 3 cups ☐ .

Meals: One hot meal each day ☐ , 2 hot meals each day ☐ . The hot meal (s) is (are) consumed at home ☐ , at the base ☐ , in a restaurant ☐ , combination of home/base ☐ , or home/restaurant ☐ .

Fig. 1. Questionnaire used to obtain information about the subjects' life style.

4. An inquiry form (Fig. 1) is used to obtain information about the subjects' smoking and dietary habits, and habitual physical activity. These forms are completed by one of the authors during his examination of the subject.  
 Information about alcohol consumption may be incorrectly stated in this questionnaire, because alcohol abuse in a subject might lead to loss of his medical classification. We have therefore limited the inquiry to frequencies of alcohol intakes which will lead to loss of the licence to operate motor vehicles in Norway.
5. A venous blood sample is obtained from each subject in fasting condition (12 hours). The serum concentrations of total cholesterol, HDL cholesterol and triglycerides are analyzed using the Biochemical Test Combinations of Boehringer Mannheim GmbH (West-Germany). The accuracy is within 3%. The LDL fraction of the serum cholesterol was estimated according to the "Friedewald Equation" (7).

### Preliminary results

The program was initiated January 1980 and at the present time only 58 subjects have been examined. Thus it is important to note that due to the small number of subjects the results may only be indicative.

The treatment of the results was performed by an IBM 370/148 computer, employing the statistical package BMDP-77, University of California.

Principally we studied how the serum lipoprotein concentration was related to the age of the subjects.

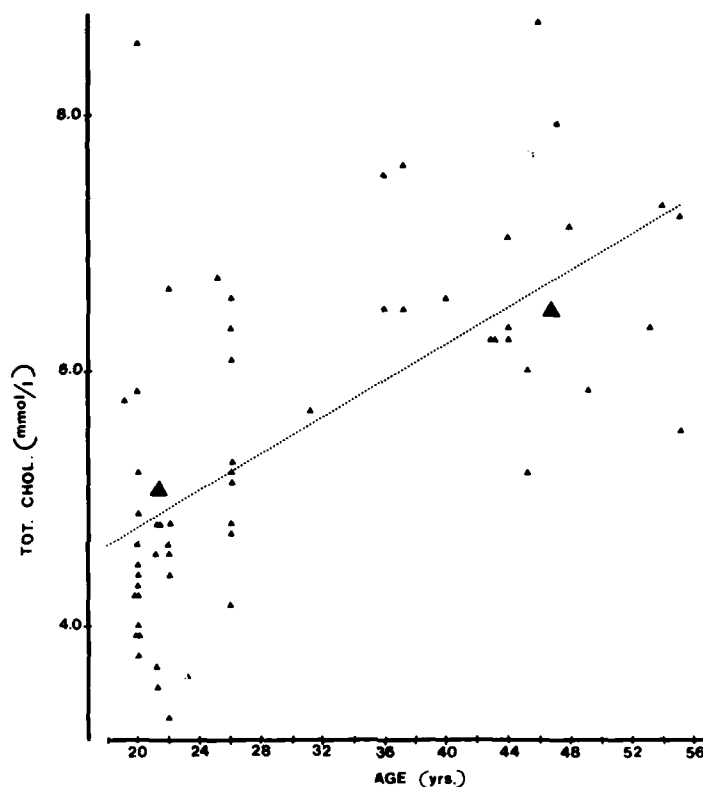


Fig. 2. Serum total cholesterol related to the age of the subjects. The regression line is calculated according to the method of the least quadrates. The big symbols depict average concentrations in a Norwegian population of men.

The serum cholesterol concentration is positively correlated ( $r=0.631$ ) to the age of the subjects, although the results are scattered. Between the age of 20 and 25 years most of the subjects have cholesterol concentrations below the 5.1 mmol/l, obtained in the Tromsø Heart Study 1979/80 (D.S. Thelle, pers. comm.) on men in the same age group, and regarded as a population average. This fairly favorable initial condition does not seem to persist inasmuch as the older subjects (45-49 years) have reached the concentration of 6.5 mmol/l which is average for a Norwegian population of the same age.

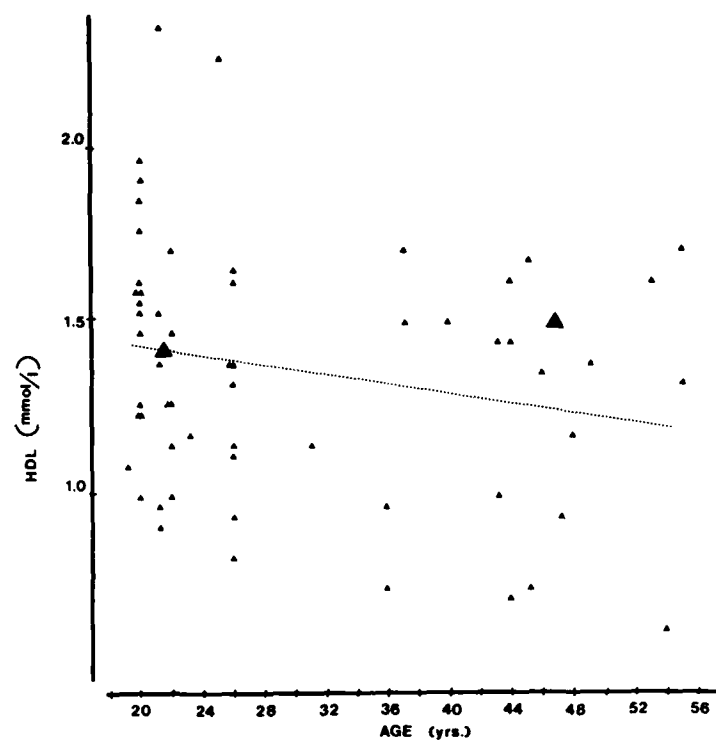


Fig. 3. Serum HDL cholesterol concentrations related to the age of the subjects.

The HDL cholesterol concentrations of the young subjects (Fig. 3) coincided well with the population average of 1.4 mmol/l. However, the older subjects have slightly reduced HDL cholesterol concentrations, contrasting previous reports (3).

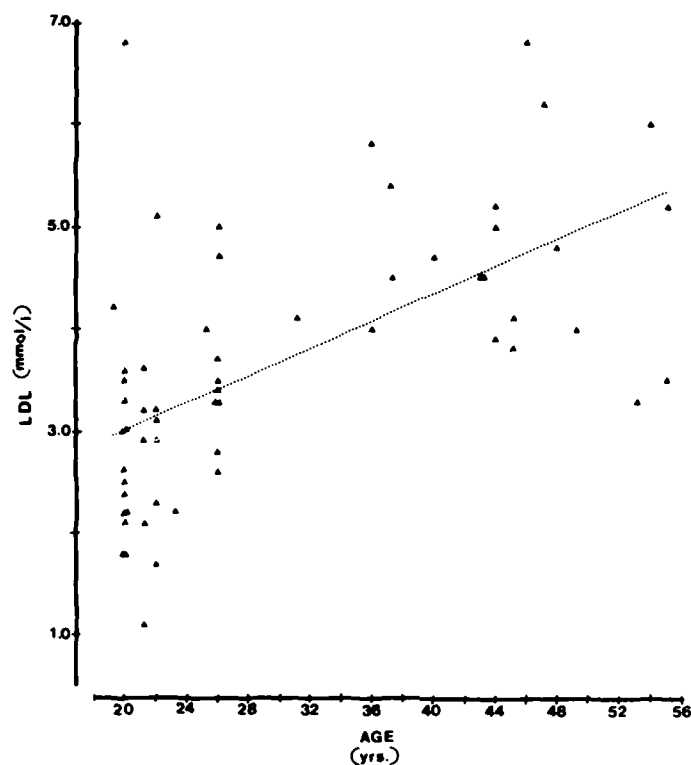


Fig. 4. Serum LDL cholesterol concentrations related to the age of the subjects.

This unfavourable development with age is also apparent when the LDL-cholesterol concentrations are estimated (Fig. 4). As shown in figure 4 there is a rising trend and many have concentrations above 3.9 mmol/l. This level might be considered clinically unfavorable.

The triglyceride concentrations obtained in the Tromsø Heart Study was 1.51 mmol/l in the youngest group (20-24 years) and 1.83 mmol/l in the oldest group (45-49 years), however, these subjects were non fasting. As shown in Fig. 5 most of the subjects of the present study exhibited lower concentrations.

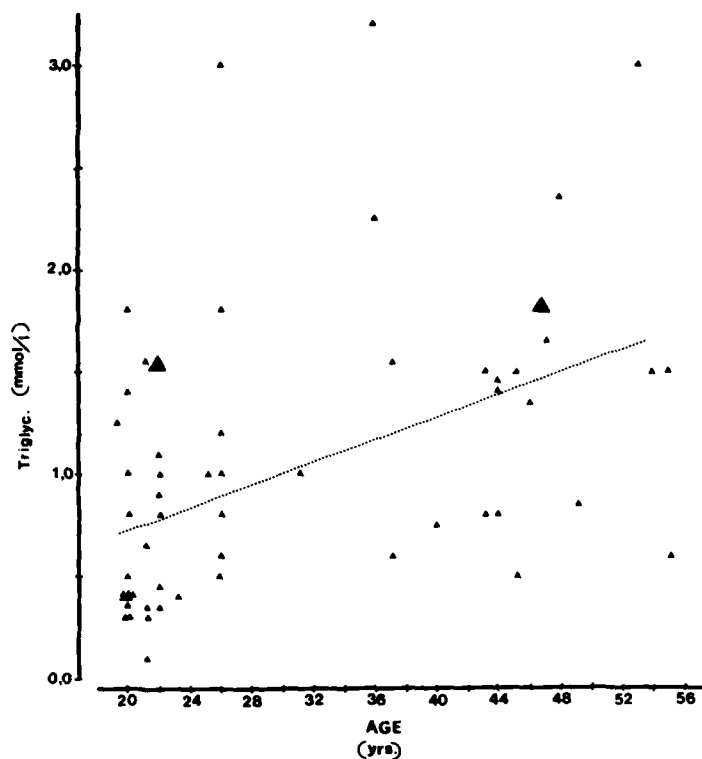


Fig. 5. Serum total triglyceride concentration related to the age of the subjects.

Since these preliminary results generally indicate an unfavourable development with age with regard to CHD risk factors, it would be interesting to investigate if there is a change in life style with age.

	No. of cigarettes each day		Alcohol conc. in blood above 0.05% Times/week		Weekly no. of exercise bouts	
	0	>20	< 1	> 1	2-3	0
Age (years)	25.8	46.5	27.1	31.1	23.6	43.8
$\pm$ S.E.M.	2.1	2.5	2.0	3.1	1.4	4.0

Fig. 6. This table depicts the average age ( $\pm$  S.E.M.) of the subjects separated in sub-groups according to their smoking and drinking habits, and habitual physical activity.

Fig. 6 lists the average age of the subjects, separated according to their habitual physical activity, smoking and drinking habits. As demonstrated in the figure there is a uniform trend towards the oldest subjects smoking and drinking more and exercise less.

Although the pathology of CHD is multifactorial the results indicate increased risk with age in the present group. In order to reduce this development of CHD risk factors all subjects should be repeatedly urged to modify their smoking and dietary habits and increase their level of physical activity. The present results might indicate that when subjects who exercise 2-3 times each week are compared to those who never exercised, the exercising subjects tended to have lower weight and fat content, lower concentrations of total cholesterol, LDL cholesterol, triglycerides and higher concentrations of HDL cholesterol. These results are not corrected for age, which will be possible when the number of subjects are increased. We believe, however, that each person has to reconsider his own life situation, and decide on measures which is a combination of smoking and dietary adjustments and increased physical activity. It is interesting to note that Hickey et al. (8), who screened 15 171 men for coronary risk factors as part of the Irish Heart Foundation MEDISCAN programme, found decreasing levels of risk factors with increasing leisure activity, independent of age. No such relationship was found in the case of work activity. This finding might indicate that the exercising group of subjects generally live more healthy, in terms of smoking and dietary habits. However, if this is caused by the exercise, or if the generally better health make exercise more attractive for these subjects, might be a problem of future investigation.

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# CHANGES IN PHYSICAL FITNESS DUE TO VARIATIONS IN PHYSICAL ACTIVITY AND DIET

By

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The young males who apply for military flying training may be profitably used in long term studies of disease processes: Selection takes place at an age when most candidates enjoy the good health and vitality of early youth. During the screening procedures their psychological and physiological fitness are evaluated, and the applicants are interviewed by experienced and high critical officers before they are accepted. Moreover, successful applicants are subjected to a careful medical examination in order to exclude anyone with a bodily disorder. Finally those retained for advanced training, have demonstrated a determined effort to pursue a career in military aviation. Since the investments in these men are to be considerable, and incidents of ill health are costly - a possible hazard to the community in general as well as a personal nuisance - they are placed under continuous medical care throughout their flying careers. Under such circumstances one would expect an exceptionally good health profile among military aviators at the various age levels compared to that of the population in general. In our experience, this assumption may not be correct. It would be of great interest, therefore, to try to determine at what age military aviators start to exhibit signs of deteriorating health.

At the Institute of Aviation Medicine of the Royal Norwegian Air Force (IAM, RNoAF) this question emerged approximately 10 years ago, when it was noticed that young pilots returning from basic and advanced flying training in North-America, seemed to have put on weight beyond the predictions one would make from the standard tables of corresponding values for height and weight which are available for the Norwegian population. Since an exercise electrocardiogram already at that time was routinely performed on air crew of the RNoAF before and after the training period in North-America, it was decided to objectively address this problem in some detail. If it is accepted that a net gain body weight with no simultaneous increase in aerobic capacity is usually a sign of obesity with undesirable physiological consequences, such a finding would be interpreted as an early, but nevertheless, serious sign of physical degeneration in young air crew.

Cardiovascular diseases are known to be the most common cause of disability or death in middle-aged Norwegian males. Several risk factor analyses with 10 to 15 thousand individuals participating indicate that the high risk groups may be identified already at an early stage. Therefore, a finding of decreased physical fitness has been tentatively defined as the starting point of a process eventually leading to impaired health.

## Material and Methods.

During the 5-year period 1972-77 122 young pilots and navigators of the RNoAF were examined on 3 separate occasions. First, when selected for initial, graded flying and military training (Stage I). Second, immediately before leaving Norway to be trained to Wing Standards in North-America (Stage II). Third, upon their return to Norway (Stage III).

The average age of the subjects when joining the RNoAF was  $20.4 \pm 1.3$  years (S.D.). All subjects met with the medical requirements of the RNoAF, and equally, those of the host nation. The body weight was determined to the nearest 500 g.

The maximal aerobic power ( $\dot{V}O_2$  max per kg body weight) was assessed from a single submaximal work load on a bicycle ergometer utilizing the heart rate with the Åstrand-Rhyming nomogram (Åstrand and Rhyming 1954). The bicycle ergometer was electromagnetically braked (Siemens-Elcoma 380 B, Stockholm, Sweden). The pedalling rate was 60 rotations per minute. The bicycle seat height was adjusted to suit each of the subjects. The subjects were dressed in shorts, and the room temperature maintained between 18°C and 20°C.



The ECG was registered on a multichannel recorder (Elema-Schönander Mingograph 34) and continuously displayed on a oscilloscope. The indifferent ECG electrode was strapped into the forehead while 6 monopolar electrodes recorded the precordial ECG at conventional sites on the chest. To familiarize the subjects with the bicycle, the load was initially set at 100 W the heart rate (HR) observed during 2-3 min of exercise. The load was then adjusted so that the HR after 6 min of bicycling would fall within the range of 130-160 beats per min. The HR was accepted as stable if it differed by less than 5 beats/min in the 5. and 6. minute of testing. The average of these two values was taken as the final HR of the work period. Otherwise the test was continued until the above criteria were established. The predicted maximal oxygen uptake was corrected for age according to Åstrand (1960). Student's t-test was used for statistical treatment of the results, and  $p = 0.05$  was regarded as significant.

#### Results.

Previous to service in the RNoAF most subjects were attending high school/college, where organized physical activity is compulsory. The average maximal oxygen uptake of the subjects at the time of entering the service (Stage I) was  $3.2 \pm 0.1 \text{ l min}^{-1}$  (S.E.M.), the average weight was  $71.5 \pm 0.6 \text{ kg}$  (S.E.M.) and the mean aerobic power was  $45.0 \pm 0.8 \text{ ml min}^{-1} \text{ S.E.M.}$

During the next  $10.0 \pm 0.2$  months (S.E.M.) the trainees underwent basic military training which included 2 weekly hours endurance training (running) for about 8 weeks. During the following flying period of about 10 weeks, they were subjected to no organized physical activity. During the remaining period of about 21 weeks they underwent officer training which included on the average 5 hours of endurance exercise (running) every week. Averaged for this whole period of 10 months, 3 hours per week used for endurance exercise, to which the physical activity of regular infantry training has to be added. At the end of this period (stage II) the average weight had increased to  $72.6 \pm 0.6 \text{ kg}$  (S.E.M.). However, this gain in body weight was not significant. The maximal  $\text{O}_2$  uptake however, had increased significantly ( $p = 0.001$ ) by 9.4% to  $3.5 \pm 0.1 \text{ l min}^{-1}$  and the maximal aerobic power by 6.2% to  $47.8 \pm 0.7 \text{ ml min}^{-1} \text{ kg}^{-1}$  ( $p = 0.005$ ).

During the following  $11.6 \pm 0.1$  months (S.E.M.) the pilot trainees underwent basic flying training in North America. During this period all physical activity was voluntary. With a consequent drop in the number of participating trainees. Upon returning to Norway (Stage III) their average weight had increased significantly to  $74.6 \pm 0.7 \text{ kg}$  (S.E.M.) ( $p = 0.005$ ). Moreover, the average maximal  $\text{O}_2$  uptake had become reduced significantly to the initial value of Stage I  $3.2 \pm 0.1 \text{ l min}^{-1}$  (S.E.M.) ( $p = 0.005$  and, consequently, the maximal aerobic power had decreased significantly by 7.7% to  $44.1 \pm 0.6 \text{ ml min}^{-1} \text{ kg}^{-1}$  (S.E.M.) ( $p = 0.001$ ) which is slightly below the Stage I value.

Changes in dietary habits were inquired about upon the return to Norway (Stage III). Although hard facts obviously cannot be presented, the information obtained strongly indicated that the food intake had increased in amount as well as towards consumption of foods characterized by a high content of carbohydrates and fat.

#### Conclusions:

The investigation reported in this paper has recently been expanded considerably in the health profile programme of the RNoAF Institute of Medicine. Also, the procedures have been reviewed and, hopefully, improved in order to launch a more well controlled study. However, it seems safe to conclude already at this stage that when programmes of compulsory exercise is abolished and the diet simultaneously undergoes a marked change in an undesirable direction, physical fitness deteriorates very rapidly with consequent bodily degeneration.

Moreover, it is our experience that subjects conspicuously affected do little to improve their way of life, with the prospect of ending up in the high risk group for cardiovascular disease already 10-15 years after having achieved Wing Standards. Unless

checked by appropriate regulations it appears that what looks like an insignificant episode in early life, may be the foundation of a considerable waste of air crew.  
Fig. 1.

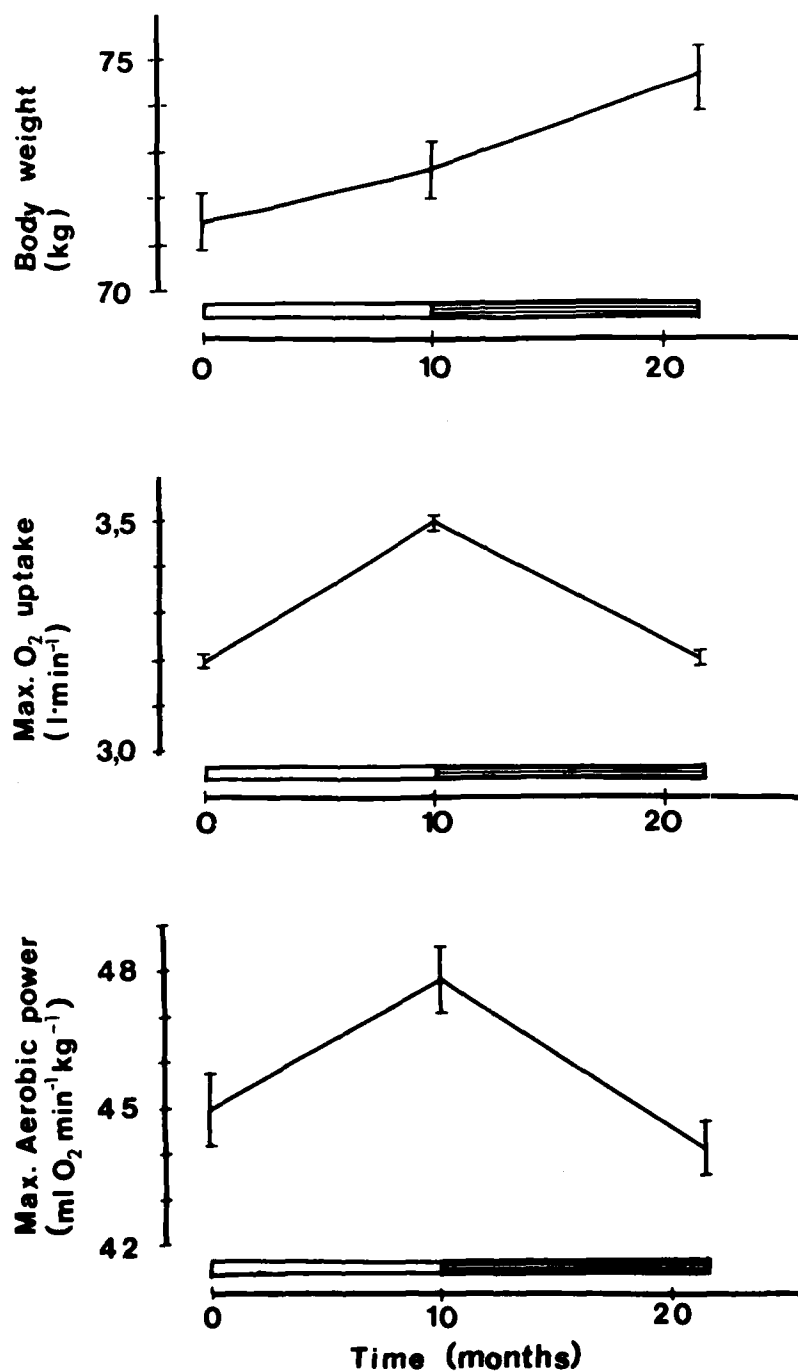


Fig. 1. Body weight, maximal oxygen uptake and maximal aerobic power of the subjects at the time of entering the service, before basic flying training in North America and upon returning to Norway. The vertical bars depict standard error of the mean.

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DISCUSSION

DR W S MYLES (CA)

Values for  $VO_2$  max. indicate that the test subjects had a very narrow range of values. Is this a result of the selection process?

AUTHOR

A narrow range for  $VO_2$  max. resulted for two reasons:

1. The figures given are the mean and standard error of the mean.
2. Sampling was done from an homogenous population.

## PHYSIOLOGIC CRITERIA RELATED TO G TOLERANCE IN COMBAT AIRCREW

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### SUMMARY

Increased +G<sub>z</sub> stress demands continue to be placed on modern high performance fighter aircraft pilots. Precise definition of normal +G<sub>z</sub> tolerance along with a full understanding of the physiologic and anatomic factors that influence +G<sub>z</sub> tolerance is therefore of increasing importance. If certain subtle medical abnormalities are associated with altered +G<sub>z</sub> tolerance it will be necessary to develop diagnostic methods to evaluate these abnormalities, to find in what way they affect +G<sub>z</sub> tolerance, and further for medical standards to recognize the limitations. With the cost of fighter aircraft becoming tremendously high, along with the associated high cost of training aviators to fly them, it will become more important to assure safety by selecting only those individuals most suited to tolerate the multistress environment of the fighter aircraft. If measurable parameters are associated with increased +G<sub>z</sub> tolerance, it might be possible in the future to establish high performance fighter aircraft selection standards so that a group of aviators with super high +G<sub>z</sub> tolerance could be selected to maintain air superiority. Initial studies measuring the +G<sub>z</sub> tolerance of 59 USAF aircrewmembers undergoing aeromedical evaluation were made on the USAF School of Aerospace Medicine (USAFSAM) human centrifuge using a specific centrifuge stress medical evaluation protocol. Specific clinically measurable parameters were found to be associated with +G<sub>z</sub> tolerance. In addition, the use of the centrifuge stress medical evaluation protocol to detect medically significant cardiac dysrhythmias was investigated. The types of dysrhythmias and their time of onset give added insight into the physiologic response of man to +G<sub>z</sub> stress.

### INTRODUCTION

Today's military aircrewmembers represent large financial investments because of their expensive training, continual education, and on-the-job experience, all of which contribute to making them the most valuable manpower, on a per-capita basis, in our society (1,2). For this reason, every effort should be made to retain aircrewmembers if they have normal clinical evaluations and are not judged medically to be at increased risk for sudden incapacitation. The question of what normal really is frequently becomes a perplexing problem, especially when it is necessary to subject these aircrewmembers to uniquely stressful environments.

Modern high performance combat fighter pilots are being subjected to an ever increasing mentally and physically stressful aerial combat environment. Medical standards must recognize that the new fighter aircraft can exceed the +G<sub>z</sub> tolerance of even a completely healthy pilot. Standards must also prevent an individual with an altered tolerance to this type of stress from being placed at undue risk. To aid establishment of medical standards for high performance fighter aircraft pilots we have evaluated aircrewmembers with subtle medical irregularities on the USAFSAM human centrifuge using a centrifuge stress medical evaluation protocol (3) to determine if their condition was specifically +G<sub>z</sub>-sensitive. To assure non +G<sub>z</sub> sensitivity the aircrewmembers must have an acceptable minimum +G<sub>z</sub> tolerance and also not manifest any clinically significant cardiac dysrhythmias or other symptoms. It is of additional interest to determine if certain clinically measurable parameters are associated with enhanced +G<sub>z</sub> tolerance, such that future fighter pilot selection standards could be designed to select individuals with very high +G<sub>z</sub> tolerance (4). The usefulness of the centrifuge stress medical evaluation protocol in the clinical evaluation of cardiac dysrhythmias and the frequency of occurrence of dysrhythmias during +G<sub>z</sub> stress was also investigated. The type of dysrhythmia and its relationship to the application of the +G<sub>z</sub> force gives information on the physiologic response to +G<sub>z</sub> stress. A comparison of the centrifuge stress test to the usual clinical methods of dysrhythmias detection (treadmill testing and Holter monitoring) was made.

### METHODS

G-tolerance Study: Certain aircrewmembers undergoing aeromedical evaluation at the Clinical Sciences Division of USAFSAM have been referred for centrifuge testing in an effort to determine if their medical condition was sensitive to +G<sub>z</sub>. Fifty-nine male aircrewmembers undergoing clinical aeromedical evaluation were tested on the human centrifuge utilizing a specific medical evaluation protocol consisting of four profiles as shown in Table I. The centrifuge configuration and testing procedures have been described in detail (3, 5). The endpoint in determining all +G<sub>z</sub> tolerance was 100% peripheral light loss or 50% central light loss. The patients did not wear anti-G suits.

The results of the centrifuge test include +G<sub>z</sub> tolerance, maximal heart rate response, and the electrocardiographic response to each profile. The centrifuge test results were correlated with the results of the coincident clinical evaluation being

carried out. Clinical parameters were obtained from the procedures shown in Table II. The treadmill exercise test was carried out using the USAFSAM protocol (6). The majority of the patients undergoing centrifuge testing fall into six diagnostic categories as shown in Table III. The +G<sub>z</sub> tolerance data for the total group of medical evaluatees and for the six medical subgroups are shown in Table IV. The remaining three subjects not included in the medical subgroups were two patients with ophthalmologic abnormalities and one patient with a history of thromboembolic disease. These diagnoses were the referral diagnoses, representing the aeromedical reason why those patients were undergoing clinical evaluation at USAFSAM.

**Dysrhythmia Study:** To evaluate the effectiveness of the medical evaluation protocol in the evaluation of dysrhythmias, three groups of 20 subjects each were selected. Twenty healthy volunteer USAF subjects, who were members of the USAFSAM acceleration stress panel constituted one group. The other two groups each consisted of 20 apparently healthy asymptomatic aircrewmembers undergoing aeromedical evaluation at USAFSAM. The first clinical group was composed of individuals undergoing evaluation for a recently discovered dysrhythmia (dysrhythmia patients); and the second clinical group, of individuals without a primary referral diagnosis of dysrhythmia (non-dysrhythmia patients). This second group consisted of individuals with very mild aortic or mitral valvular abnormalities, abnormal exercise tolerance tests, hypertension, or unexplained loss of consciousness. None of the patients were symptomatic and all considered themselves to be in excellent health.

The two groups of aeromedical evaluation subjects all underwent +G<sub>z</sub> stress testing using only the medical evaluation protocol. The group of panel members<sup>2</sup> was subjected to routine +G<sub>z</sub>-stress profiles used at USAFSAM including the aeromedical protocol and in addition to various more strenuous high sustained G-stress runs (such as simulated aerial combat maneuvers). Anti-G suits were worn by all panel members except those exposed only to the aeromedical protocol. The maximal +G<sub>z</sub> level in all exposures was limited to +7G<sub>z</sub>.

In addition to electrocardiographic monitoring during the centrifuge G-stress all subjects were monitored during maximal treadmill exercise stress testing and during 24-hour ambulatory Holter monitoring. The Holter monitor was worn 24 hours immediately following both treadmill and acceleration stress. The panel members additionally wore the Holter monitor for the 24 hours immediately preceding the +G<sub>z</sub> stress. For Holter monitoring, a single V<sub>1</sub>-like lead system was used, as previously<sup>2</sup> advocated, to facilitate the identification of ectopic beats (7). The recordings were analyzed using an Avionics 660A scanner capable of review up to 120 times real time. All treadmill tests were performed in the morning, before 12:00 after an overnight fast. All centrifuge tests were performed in the afternoon, between 1:00 and 4:00 pm with a minimum of two hours passing between the last meal and the acceleration exposure. Not only were all subjects counseled about ensuring comparable activities before and after both stress tests, additionally a diary was kept of all psychophysiological events. Statistical analysis using two-tailed unpaired t-tests were performed in comparing the results of the three groups. Two-tailed paired t-tests were used to compare results of the two different stress tests within a group.

## RESULTS

**G-tolerance Study:** Although no statistically significant differences based on Student's t test were found when comparing the +G<sub>z</sub> tolerance data for the medical subgroups, a consistent trend was noted for two of the subgroups. The hypertensive subgroup was found to be consistently higher than the mean, and the abnormal exercise test group was consistently lower than the mean. The remainder of the subgroups were found to have mixed +G<sub>z</sub> tolerance trends. Additional clinical parameters associated with the hypertensive subgroup included the highest heart rates pre-centrifuge testing, the highest heart rates during maximal treadmill exercise testing, the most flying hours, the highest systolic blood pressure during maximal treadmill exercise testing, and the greatest percent body fat. The abnormal exercise test subgroup consisted of patients with an abnormal response (ischemic, hypertensive or arrhythmic) to an exercise stress test (double Master's or treadmill exercise tests). The abnormal exercise test subgroup was lowest in gross body weight and highest in age.

Based on previous +G<sub>z</sub> tolerance standards, the overall group was essentially identical in mean +G<sub>z</sub> tolerance to a larger group of medical evaluatees (8) and to healthy USAF aircrewmembers (9). The complete set of +G<sub>z</sub> tolerance standards are shown in Table V. The corresponding heart rate standards for the profiles are shown in Table VI. Both the heart rate response standards and the +G<sub>z</sub> tolerance standards are based on the mean for the overall group  $\pm 1$  S.D.

Utilizing these standards, only 5% (3 of 59) of the patients in the study demonstrated consistently high +G<sub>z</sub> tolerance on all four test profiles. Likewise, only 5% demonstrated consistently low +G<sub>z</sub> tolerance. Consistently average +G<sub>z</sub> tolerance was seen in 29% (17 of 59) of the patients, while the remaining 61% had a mixed +G<sub>z</sub> tolerance.

In an effort to determine if certain clinical parameters were associated with high or low +G<sub>z</sub> tolerance, the group of 59 patients was divided into high and low +G<sub>z</sub> tolerance<sup>2</sup> groups based on the above standards. The high-tolerance group (HTG) consisted of 10% of patients with highest overall +G<sub>z</sub> tolerance and the low-tolerance group (LTG)

the 10' of patients with the lowest overall  $+G_z$  tolerance. The means for the HTG and the LTG compared to the overall  $+G_z$  tolerance standards are shown in Table VII.

The clinical parameters for the HTG and LTG were then compared as shown in Table VIII. Other associated clinical findings for the HTG and LTG are given in Table IX as a fraction of the total (6) in each group.

**Dysrhythmia Study:** The characteristics of the three subject groups for the dysrhythmia study are shown in Table X. The panel members were younger ( $p<.001$ ) and shorter ( $p<.01$ ), as a group, when compared to the two patient groups. Most of the panel members were young enlisted airmen stationed at Brooks AFB. The patient groups were aircrewmembers, nearly all officers already having undergone specialized pilot or navigator training. No statistically significant differences existed between the two patient groups. A description of the relative stress during the centrifuge test and the treadmill exercise test are shown in Table XI. No statistically significant differences were found between the groups, either on maximal time or maximal heart rate, during treadmill stress. The centrifuge test results revealed that the stress panel was exposed to significantly higher  $G_z$ -stress ( $p<.001$ ), of  $+7.0G_z$ , as compared to  $+5.3G_z$  and  $+5.4G_z$  for the patient groups. This greater resultant stress produced a significantly higher heart rate ( $p<.001$ ) for the stress panel as compared with that of the patient groups. No statistically significant difference was found between the maximal heart rate for the stress panel members during treadmill testing and centrifuge testing, based on a two-tailed paired t-test. Statistically significant differences ( $p<.001$ ), found between the centrifuge test maximal heart rates and the treadmill maximal heart rates for both patient groups, revealed a higher heart rate during treadmill testing.

Heart rate analysis was carried out for each of the Holter monitoring periods. In no case was there a significant difference (two-tailed paired t-test) in the heart rates during any similar 6-hour subdivision, when comparing the 24 hours post-treadmill with the 24 hours post-centrifuge, for either the stress panel members or the patient groups. No differences were found when comparing the pre-and post-centrifuge stress test 24-hour periods for the stress panel members. Holter monitoring periods varied between means of 20.9 hours and 22.3 hours.

Dysrhythmia analysis was performed for each stress period and all Holter monitor periods. The dysrhythmias are listed for each group in Table XII. The atrial dysrhythmias consisted of premature atrial contractions, ectopic atrial rhythm, sinus arrhythmia (rate variance 25 bpm or more between successive beats), sinus bradycardia (50 bpm or less) and atrial tachycardia. Junctional dysrhythmias included premature junctional contractions and supraventricular tachycardia. Ventricular dysrhythmias were divided into ventricular I, which included simple premature ventricular contractions (less than 5/min), whereas, ventricular II consisted of frequent or multiform premature ventricular contractions, ventricular bigeminy or trigeminy, ventricular pairing, and ventricular tachycardia. The dysrhythmias in Table XII are given as the percentage of subjects in which a particular dysrhythmia occurred as compared to the total number of subjects in a group. Due to the wide range and few similarities, the dysrhythmias were not quantified as to the total number of ectopic beats or the number of ectopic beats per number of normal beats that occurred. They are given only as whether or not one or more ectopic beats occurred during each time period, such as the time period of the treadmill testing, the time period of the 24-hour post-treadmill Holter monitoring, or the time period of the centrifuge testing. A comparison of the consistency of the time of occurrence for the dysrhythmias is given in Table XIII. This table lumped all dysrhythmias together and makes no distinction as to the exact type of dysrhythmia which occurred.

## DISCUSSION

The evaluation of G-sensitive aircrewmembers using the centrifuge medical evaluation protocol has been described. The variability in  $+G_z$ -tolerance and heart rate response associated with each of the profiles has been determined (8). The standard deviations in  $+G_z$ -tolerance that can be expected when using the profiles are  $GOR(1)=0.38G_z$ ,  $ROR(PASS)=0.22G_z$ ,  $GOR(2)=0.34G_z$ , and  $GOR(S)=0.39G_z$ . The standard deviations in the maximum heart rate for each profile are  $GOR(1)=11bpm$ ,  $ROR(PASS)=8bpm$ ,  $GOR(2)=8bpm$ , and  $GOR(S)=8bpm$ . The medical evaluation protocol is used to measure  $+G_z$ -tolerance and to determine possible sensitivity to  $+G_z$  induced cardiac dysrhythmias. Case reports describing the association of G-induced loss of consciousness and certain dysrhythmias demonstrate the usefulness of G-induced dysrhythmia analysis (9,10).

**G-tolerance Study:** Correlation of the  $+G_z$  tolerance with clinical diagnoses and clinically measurable physiologic and anatomic parameters provides a unique opportunity to gain a more thorough understanding of the factors that affect the human response to  $+G_z$  stress. The cost of high-performance aircraft is astronomical and rises every year. Aerial combat in these aircraft produces a severe multi-stress environment for aviators. For these reasons it is possible, that, in the very near future, specific qualifications will be placed on aircrewmembers selected to fly this type of aircraft. Current USAF flying status is unconditional, since an aircrewman medically qualified to fly is medically qualified to fly all USAF aircraft. If certain subtle medical abnormalities compromise  $+G_z$  tolerance, then specific selection and waiver criteria should reflect this compromised function. This could mean that a pilot might be retained to fly all aircraft except the high-performance fighter aircraft capable of producing high  $+G_z$ .

Although no specific medical subgroup unequivocally demonstrated an altered  $+G_z$

tolerance, certain trends for future investigation have been identified. At present, certain clinical parameters do appear to be associated with high  $+G_z$  tolerance, these are not necessarily optimum attributes for a high-performance fighter aircraft pilot. The relaxed  $+G_z$  tolerance in healthy men (11) was shown to be positively correlated with age (for ROR's) and with age and weight (for GOR's). Although not statistically significant, our results were essentially in agreement with these findings. A statistically significant negative relation of  $+G_z$  tolerance with height was seen ( $p=0.033$ ). This finding of increased  $+G_z$  tolerance with shorter stature is not completely surprising. Given similar perfusion driving pressures generated by the cardiovascular system, then a decrease in heart to eye/brain distance will result in enhanced  $+G_z$  tolerance. A decrease in effective vertical heart to eye/brain distance is well known to increase  $+G_z$  tolerance, as demonstrated by  $+G_z$  tolerance enhancement using tilt-back seats (12). If heart to eye/brain distance is indeed decreased with decreasing stature, then  $+G_z$  tolerance should increase with decreasing height. The most significant difference ( $p=0.003$ ) between the HTG and LTG was blood cholesterol, being higher in the HTG. Triglycerides likewise followed the same trend as cholesterol being higher in the HTG ( $p=0.044$ ). Blood pressure, during treadmill exercise (maximum systolic blood pressure  $p=0.038$  and maximum diastolic blood pressure  $p=0.043$ ) and rest (systolic blood pressure  $p=0.014$ ) and a lower maximum heart rate during treadmill testing ( $p=0.30$ ) were found for the HTG. Whether or not the clinical parameters associated with the HTG are independent or dependent must be further refined. Certainly as age increases it is usual for weight, experience (flying hours), blood pressure, and percent body fat to increase. It appears from this preliminary investigation that  $+G_z$  tolerance also increases in harmony with these parameters. Both cholesterol and triglycerides along with hypertension are well known to be associated with increased atherosclerotic cardiovascular disease. This vascular disease, which includes hardening of the vessels, could be associated with more rigidity and less distensibility, thereby giving a resultant increase in  $+G_z$  tolerance. A higher eye-level blood pressure in itself is what is desired to maintain cerebral and retinal perfusion during head-to-foot acceleration; therefore, it is not surprising that a higher blood pressure would be associated with a higher  $+G_z$  tolerance. Further association with blood pressure was evidenced by 5 of 6 subjects having an abnormal (hypertensive) response to orthostatic tilt-table testing, and 3 of 6 subjects having a clinical diagnosis of hypertension. Previous studies have failed to show a positive correlation of  $+G_z$  tolerance and the response to tilt-table testing (13). In agreement with other studies (13, 14), no relationship between  $+G_z$  tolerance and aerobic capacity (treadmill test max time) was found. Overall, the high  $+G_z$  prototype would seem to be the older, shorter, heavier, more experienced (more flying hours and more fighter pilot experience) individual with a higher blood pressure, higher hematocrit, higher cholesterol and triglycerides, hypertensive response to tilt-table testing, and higher blood pressure response to maximum treadmill exercise testing. Many of these apparent G-protective factors have associated with them increased cardiovascular disease risk, which is not desirable for pilot selection or retention. The low  $+G_z$  prototype was demonstrated to be a taller, thinner, less experienced (less flying hours and less fighter pilot experience), individual with lower blood pressure, lower hematocrit, more arrhythmias, and be more apt to undergo cardiac catheterization.

The patients referred for centrifuge testing are generally quite healthy, although they do manifest some type of cardiovascular deviation from normal. The patients in this study overall have  $+G_z$  tolerance insignificantly different from healthy airmen. It is, therefore, not unexpected that the differences between the medical subgroups might be of small magnitude. Continued investigation of the subtle differences manifested by various subgroups may well become significant with larger numbers of patients in each subgroup. This work importantly does indicate that certain parameters are associated with high and low  $+G_z$  tolerance.

Dysrhythmia Study: Determination of the effects of physical stress testing on the induction of various dysrhythmias is important for defining the sensitivity of the stress test in uncovering dysrhythmias and in ensuring overall stress test safety. Although the three groups were all healthy, certain differences were present between the groups. As already stated, the panel members were younger and shorter than the patient groups. The younger age of the panel members reflects the population from which these individuals are chosen. Their shorter stature was consistent with previous observations showing increased  $+G_z$  tolerance correlation inverse with height. Since the stress panel is composed of individuals who are able to tolerate high levels of sustained  $+G_z$  during physiologic experimentation, the shorter individuals are selectively able to perform these duties with less effort than taller cohorts.

The panel members were exposed to different  $+G_z$  profiles which were significantly more stressful than the patient groups who were exposed to the medical evaluation protocol. This increased stress during centrifuge  $+G_z$  acceleration produced more dysrhythmias than did maximal treadmill exercise stress in the panel members. At least 50% of the panel members having had a dysrhythmia during centrifuge testing. There was no increase in the dysrhythmias seen during Holter monitoring post-centrifuge testing as compared to the Holter monitoring during the pre-centrifuge test period. In addition, no difference was found during the post-treadmill period as compared to either pre- or post-centrifuge testing.

For the non-dysrhythmia patient group, more dysrhythmias were noted during stress-testing periods than during the post-stress 24-hour periods. Essentially no difference was found in the kind or occurrence of dysrhythmias seen during centrifuge testing or maximal treadmill testing. More dysrhythmias were observed in this group both during and after stress, as compared to the panel members, but less dysrhythmias than observed

in the dysrhythmia patient group. As would be expected, the dysrhythmia patients had more dysrhythmias both during and after stress than did the other two groups. Ventricular type I and II dysrhythmias were more frequent in the dysrhythmia patient group.

An analysis of the consistency of dysrhythmia occurrence revealed the panel members to have a preponderance of dysrhythmias during centrifuge stress. Little difference was found in the occurrence of dysrhythmias in the two patient groups. In all groups, substantially more dysrhythmias occurred during stress than during the post-stress Holter monitoring periods. There was not much difference observed in the frequency of dysrhythmia occurrence post-treadmill stress as compared to post centrifuge stress.

Both centrifuge testing and maximal treadmill testing are dysrhythmogenic. From a comparison of these healthy subjects, where the panel members were exposed to higher  $+G_z$  for longer periods, more dysrhythmias were observed during centrifuge testing. No increase in dysrhythmias was seen in the two aeromedical patient groups exposed to less  $G_z$  stress. This observation agrees with previous investigations of  $G_z$  stress where the frequency of dysrhythmias increases with the intensity and duration of  $G_z$  stress (16). It is probable that more dysrhythmias would have been induced during centrifuge stress testing in the two patient groups if a more stressful protocol were developed. It is currently being recommended that all USAF high-performance fighter aircraft pilots be able to successfully attain  $+7.0G_z$  for 15 sec during a 1G/sec run while wearing an anti-G suit. Our results indicate that dysrhythmias are likely to be frequent in pilots flying in a high  $+G_z$  multistress aerial combat environment. It would be of interest to compare these results with actual inflight recordings to compare the heart rates and dysrhythmia frequency as a measure of the additional stress of current aerial combat maneuvering.

Centrifuge  $G_z$  stress provides a type of physical stress different from that of treadmill exercise. Certain dysrhythmias were more frequently associated with  $+G_z$  stress. These included sinus arrhythmia and ectopic atrial rhythm. In addition, one episode of prolonged sino-atrial block (sinus arrest) occurred immediately after  $G_z$  stress in an individual who had no previous or subsequent similar disturbance. Following a gradual onset run (1G/15 sec) the subject, one of non-dysrhythmia patients, had 10 sec. of cardiac asystole with resultant loss of consciousness. In a pilot population, any condition which could predispose to sudden incapacitation, even for a short period, is important from an aeromedical standpoint. Of particular importance in the investigation of stress is whether or not the effects are persistent. Our results agree with previous work, in that no apparent residual effects were noted with respect to either dysrhythmias or heart rate, after either treadmill or centrifuge stress.

The incidence of exercise (treadmill) induced dysrhythmias in our aeromedical patient type population has been reported (17), revealing a high incidence of PVC's (35%). Ominous dysrhythmias were noted in 2.1% of the aircrew population. Dysrhythmia sensitivity for detection of coronary artery disease was about 7%. The specific group of patients referred for acceleration-stress testing are a select subset of those individuals undergoing aeromedical evaluation at USAFSAM. They represent individuals who had no disqualifications in the routine aeromedical evaluation, which always preceded the acceleration-stress test. Those individuals with aeromedically disqualifying abnormal maximal treadmill exercise test, abnormal Holter monitoring, or other abnormal clinical findings, were not referred for acceleration-stress testing. Studies in clinical medicine with symptomatic patients have shown an increased incidence of ventricular dysrhythmias in those patients with coronary heart disease when subjected to stress testing.

A high incidence of premature ventricular contractions have been noted in healthy men during stress (18, 19). The prognostic significance for coronary artery disease based on this type of dysrhythmia, therefore, depends on the clinical status of the patient (20). Dysrhythmias have been shown to increase with age (21). In our group, the dysrhythmia subgroup had the oldest subjects. Since this subgroup was specifically selected on the basis of the presence of a dysrhythmia, it is therefore, impossible to assess the effect of age in this study.

Factors other than myocardial ischemia can initiate dysrhythmias. Since recent studies (22) indicate the absence of myocardial ischemia in normal animal models during levels of  $+G_z$  stress similar to those experienced in this study, it would appear that other factors present during  $+G_z$  stress are responsible for dysrhythmias. Previously suggested factors include: a) changes in position and mechanical stresses on the heart; b) changes in cardiac filling; and c) effects of sympathetic nervous system stimulation and increased catecholamine levels (23). Undoubtedly, all of these factors occur during acceleration-stress and increase with increased  $+G_z$  stress. The relative importance of these possible factors is unknown. If subclinical cardiovascular disease were present and added to a high sustained  $+G_z$  exposure, with resultant decrease in blood oxygenation, there could be a possibility of these observed dysrhythmias developing into a sustained serious rhythm disturbance.

In agreement with previous work (24), centrifuge acceleration-stress testing utilizing the current medical evaluation protocol does not uncover a large number of additional dysrhythmias not otherwise seen on other diagnostic tests. Unique dysrhythmias, not seen on more conventional tests, do occur during  $+G_z$  stress (25, 26). In an aeromedical community, uncovering these  $+G_z$ -induced dysrhythmias is of critical importance, since incapacitation in a pilot flying a high performance fighter aircraft could have disastrous



results. Individuals with specific susceptibility to +G<sub>z</sub>-induced significant arrhythmias must be carefully screened. For these individuals +G<sub>z</sub>-stress testing is invaluable in assuring aeromedical safety. As shown by this study,<sup>2</sup> it is probable that more dysrhythmias would be uncovered if a more stressful medical evaluation profile were included which would allow the patient to achieve the same maximum heart rate as during maximal treadmill stress.

Centrifuge acceleration-stress testing apparently is relatively as safe as maximal treadmill exercise testing. Both stress tests induce dysrhythmias and significantly elevate heart rate. These stress-induced changes are limited to the period of stress and do not significantly affect cardiac rate or rhythm in the post-stress 24 hour period. For USAF high-performance fighter pilots who are routinely exposed to repeated high sustained +G<sub>z</sub> stress during aerial combat, it is imperative to assure that they are not predisposed to +G<sub>z</sub>-induced dysrhythmias which could cause sudden in-flight incapacitation. Centrifuge stress testing is therefore a valuable tool in the aeromedical evaluation of these aircrewmembers.

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TABLE I. MEDICAL EVALUATION PROTOCOL\*

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Profile 1:	Gradual onset run, GOR(1), relaxed, onset rate 0.067 G/s.
Profile 2:	Rapid onset runs, ROR, beginning at $+2.8G_z$ for 15s, onset rate 1 G/s. Successive runs at $+0.3G_z$ increments.
Profile 3:	Gradual onset run, GOR(2), a repeat of Profile 1.
Profile 4:	Gradual onset run with straining, GOR(S) same as Profiles 1 and 3 except patient using straining maneuver to try to increase his $+G_z$ tolerance.

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\*G suits not worn. Run limit for all profiles  $+7G_z$ . Tolerance limit determined by loss of 100% peripheral green lights and/or 50% central red light.

TABLE II. CLINICAL EVALUATION PARAMETERS

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Body Morphology
Laboratory Tests
Treadmill Exercise Test
Holter Monitoring
Tilt-Table Test
Electrocardiogram
Vectorcardiogram
Echocardiogram
Cardiac Graphics
Pulmonary Function Tests
Cardiac Catheterization

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TABLE III. REFERRAL DIAGNOSES FOR CENTRIFUGE  
+G<sub>z</sub> STRESS TESTING

Aortic valvular abnormalities
Mitral valvular abnormalities
Abnormal exercise tolerance test
Cardiac arrhythmias
Hypertension
Unexplained loss of consciousness

TABLE IV. G<sub>z</sub> TOLERANCE AND MAXIMUM HEART RATE DATA FOR  
TOTAL GROUP AND MEDICAL SUBGROUPS\*

	GOR(1)	ROR(pass)	ROR(fail)	GOR(2)	GOR(5)
Total	4.7±0.8	3.3±0.5	3.6±0.6	4.4±0.8	5.3±0.7
Group	136±21	121±21	121±18	131±22	152±20
(N=59)	N=59	N=57	N=57	N=54	N=47
Aortic	4.8±1.0	3.0±0.4	3.4±0.3	4.2±0.7	5.3±0.8
Valve	135±28	120±14	120±13	121±13	153±26
(N=6)	N=6	N=6	N=6	N=6	N=5
Mitral	4.6±0.7	3.3±0.3	3.7±0.3	4.4±0.6	5.3±0.7
Valve	129±21	122±24	119±16	127±21	147±22
(N=14)	N=14	N=13	N=13	N=11	N=10
Loss	4.5±0.7	3.2±0.5	3.6±0.8	4.1±0.9	5.6±0.9
Cons	138±17	118±15	119±15	130±12	149±9
(N=7)	N=7	N=7	N=7	N=7	N=5
Abn Ex	4.4±0.9	2.9±0.5	3.4±0.4	4.2±1.0	4.8±0.9
Test	136±35	128±35	124±35	134±38	147±9
(N=6)	N=6	N=5	N=5	N=5	N=3
Hyper	5.3±0.4	3.8±0.5	4.0±0.5	5.1±0.4	5.7±0.6
(N=7)	146±19	122±15	123±14	131±17	146±24
	N=7	N=7	N=7	N=6	N=5
Arrhy	4.7±0.9	3.2±0.4	3.6±0.3	4.4±0.9	5.3±0.7
(N=16)	138±16	119±24	123±22	135±27	157±22
	N=16	N=16	N=16	N=16	N=16

\*Means ±1 S.D.

TABLE V.  $G_z$  TOLERANCE CRITERIA FOR CENTRIFUGE PROFILES

Profile 1:	GOR(1)	High:	5.6 or greater
		Low:	less than 4.0
		Average:	4.0 thru 5.5
Profile 2:	ROR	High:	4.1 or greater
	(pass)	Low:	less than 3.1
		Average:	3.1 thru 4.0
Profile 3:	GOR(2)	High:	5.3 or greater
		Low:	less than 3.7
		Average:	3.7 thru 5.2
Profile 4:	GOR(S)	High:	6.0 or greater
		Low:	less than 4.6
		Average:	4.6 thru 5.9

TABLE VI. HEART RATE CRITERIA FOR CENTRIFUGE PROFILES

Profile 1:	GOR(1)	High:	greater than 156
		Low:	less than 116
		Average:	116 thru 156
Profile 2:	ROR	High:	greater than 142
	(pass)	Low:	less than 100
		Average:	100 thru 142
Profile 3:	GOR(2)	High:	greater than 153
		Low:	less than 109
		Average:	109 thru 153
Profile 4:	GOR(S)	High:	greater than 172
		Low:	less than 132
		Average:	132 thru 172

TABLE VII:  $G_z$  TOLERANCE AND MAXIMUM HEART RATES FOR HIGH AND LOW TOLERANCE SUBGROUPS\*

	GOR(1)	ROR(pass)	ROR(fail)	GOR(2)	GOR(S)
	5.7 $\pm$ 0.4	4.2 $\pm$ 0.6	4.5 $\pm$ 0.6	5.4 $\pm$ 0.4	6.2 $\pm$ 0.4
HTG	144 $\pm$ 16	117 $\pm$ 24	119 $\pm$ 25	127 $\pm$ 26	148 $\pm$ 28
(N=6)	N=6	N=6	N=6	N=6	N=5
	3.6 $\pm$ 0.3	2.7 $\pm$ 0.3	3.1 $\pm$ 0.2	3.4 $\pm$ 0.5	4.3 $\pm$ 0.6
LTG	128 $\pm$ 17	124 $\pm$ 17	121 $\pm$ 13	123 $\pm$ 10	140 $\pm$ 16
(N=6)	N=6	N=6	N=6	N=6	N=4

\* Means  $\pm$  1 S.D.

TABLE VIII. CLINICAL PARAMETERS ASSOCIATED WITH THE HIGH AND LOW G TOLERANCE SUBGROUPS\*

Parameter	HTG	LTG	Significance Level
Age (yrs)	37±5	32±8	0.123
Height (in)	68.4±1.6	71.3±2.3	0.033**
Weight (lbs)	172±23	157±19	0.243
Flying Hours	3196 (high 5000) (low 650)	1798 (high 3860) (low 0)	0.165
Treadmill test			
Max HR (bpm)	176±7	186±6	0.030**
Max Time (min)	14.0±3.1	14.1±2.9	0.970
Max SBP (mmHg)	184±11	171±8	0.038**
Max DBP (mmHg)	91±13	72±15	0.043**
Rest			
HR (bpm)	75±17	69±13	0.533
SBP (mmHg)	135±10	115±13	0.014**
DBP (mmHg)	86±19	68±8	0.063
Lean Body Mass (lbs)	132±9	131±19	0.941
Percent Body Fat	23±8	18±13	0.204
Hematocrit (%)	48.3±0.8	45.2±0.2	0.004**
Hemoglobin (gm%)	15.8±0.6	15.1±0.6	0.068
Cholesterol (mg%)	222±35	165±10	0.003**
Triglyceride (mg%)	169±77	92±30	0.044**

\*Means ±1 S.D.

\*\*p &lt; 0.05

TABLE IX. ASSOCIATED CLINICAL FINDINGS FOR HIGH AND LOW G TOLERANCE SUBGROUPS

Parameter	Fraction of patients in HTG with associated parameter	Fraction of patients in LTG with associated parameter
Diagnosis of Hypertension	3/6	0/6
Diagnosis of Arrhythmia	0/6	4/6
Abnormal Tilt-Table Test	5/6	1/6
Arrhythmia during Holter Monitoring	1/6	5/6
Underwent Cardiac Catheterization	0/6	2/6
Abnormal EEG	0/6	1/6
Fighter Aircraft Pilot	3/6	0/6

TABLE X. DESCRIPTIVE CHARACTERISTICS OF SUBJECT GROUPS  
(DYSRHYTHMIA STUDY)\*

Group	N	Age (yrs.)	Height (in.)	Weight (lbs.)
Stress Panel				
Members	20	27.0(9)**	69.2(1.6)**	167.7(18)
Non-dysrhythmia				
Patients	20	36.6(8)	70.6(1.8)	171.8(20)
Dysrhythmia				
Patients	20	37.8(7)	71.2(2.1)	173.9(22)

\*Values represent means  $\pm$  1 S.D.

\*\*Significantly different based on unpaired t-test.

TABLE XI. STRESS TEST DESCRIPTION\*

Group	Treadmill Test		Centrifuge Test	
	Max Time (min)	Max HR (bpm)	Max +G <sub>z</sub>	Max HR (bpm)
Stress Panel				
Members	14.8(2.7)	178(8)	7.0(0)**	176(7)**
Non-dysrhythmia				
Patients	15.1(1.9)	182(9)	5.4(0.3)	157(8)
Dysrhythmia				
Patients	14.9(2.1)	180(8)	5.3(0.3)	155(7)

\* Values represent means  $\pm$  1 S.D.

\*\* Significantly different based on unpaired t-test.

TABLE XIIa. Dysrhythmia Analysis for Stress Panel Members\*

Dysrhythmia Description	Treadmill	Post Treadmill	Pre Centrifuge	Centrifuge	Post Centrifuge
Atrial	10	0	0	20	5
Junctional	0	0	5	0	5
Ventricular I	5	5	5	45	0
Ventricular II	0	0	0	10	0
Other	0	0	0	10	0
None	90	95	90	50	90

TABLE XIIb. Dysrhythmia Analysis for Non-Dysrhythmia Patients\*

Dysrhythmia Description	Treadmill	Post Treadmill	Pre Centrifuge	Centrifuge	Post Centrifuge
Atrial	30	10	---	35	15
Junctional	0	5	---	10	0
Ventricular I	30	20	---	20	15
Ventricular II	10	5	---	10	10
Other	10	10	---	15	10
None	55	60	---	50	65

TABLE XIIc. Dysrhythmia Analysis for Dysrhythmia Patients\*

Dysrhythmia Description	Treadmill	Post Treadmill	Pre Centrifuge	Centrifuge	Post Centrifuge
Atrial	35	20	---	35	25
Junctional	5	0	---	5	0
Ventricular I	50	25	---	45	30
Ventricular II	15	15	---	15	15
Other	5	0	---	5	0
None	15	35	---	10	30

\* Given as the percentage of subjects in which a particular dysrhythmia occurred as compared to the total number of subjects in the group.

TABLE XIII. CONSISTENCY COMPARISON FOR OCCURRENCE OF DYSRHYTHMIAS

	Stress Panel Members	Non-dysrhythmia Patients	Dysrhythmia Patients
Only TM	0	10	10
Only Post TM	0	5	5
Only C	45	15	10
Only Post C	5	0	0
Only Stress(TM+C)	50	25	30
Only Post-Stress (Post-TM+C)	5	5	5



## DISCUSSION

DR E ALNAES (NO)

1. What percentage of pilots sent to SAM for cardiological examination is rejected by the Board on the basis of centrifuge performance, and
2. You stated that a certain number of Flight Surgeons had significant arrhythmia during centrifuge testing. What was the total number of subjects tested, and what was their age distribution?

AUTHOR

1. The percentage of pilots disqualified from recommendation for waiver because of results obtained through centrifuge acceleration testing is very low, perhaps 1 to 3 percent per year of those referred specifically for centrifuge testing. These disqualifications are mostly due to the demonstration of G-induced significant dysrhythmia (ventricular tachycardia for instance). Recently, specific disqualification on the basis of low G tolerance has begun to enter the diagnostic realm mainly because of the new high performance fighter aircraft and the USAF's move toward categorised flying status. The percentage disqualified may well increase for these latter reasons.

2. Flight Surgeons going to fighter aircraft bases are specifically encouraged to undergo G training at USAF SAM as part of their primary course in Aerospace Medicine. In the fall 1980 class of approximately 75 to 100 individuals, 15 went through G orientation and training. Three of the 15 had a documented episode of technical ventricular tachycardia (3 or more beats in a row). The age of these individuals is in the range 28-34 years, as a rule. Since they are young, healthy individuals who have only recently successfully completed a Class II USAF flight physical we are not overly concerned about their health status. We do require an echocardiogram to be obtained, since at this point in time we consider they have a good statistical possibility of having mitral apparatus dysfunction.

DR H T ANDERSEN (NO)

Middle-aged men with slightly elevated blood pressure and sub-clinical atheromatosis are known to tolerate G stress quite well. However, when the aviator has developed hypertension and the atheromatosis gives symptoms, he may lose his flying status regardless of G tolerance.

AUTHOR

Yes, I quite agree with your comment. The results of the present study go along with G tolerance increasing with an increase in the risk factors for atherosclerotic cardiovascular disease. We have not yet analysed the clinical parameters with respect to being dependent or independent variables. I suspect many are dependent. This dilemma is unfortunate, but does point to further research that would be extremely important in our search for the individual who is most suited to maintain air superiority safely.

DR R AUFFRET (FR)

1. What was the seat-back angle during your experiments?
2. What is your experience of the appearance of arrhythmia and ECG change on lower acceleration levels (3G or 4G) for longer duration?

AUTHOR

1. The centrifuge seat back angle was 13° from the vertical position. The entire seat and centrifuge cockpit design is a mock-up of the F-15 aircraft cockpit.

2. Our experience with long duration acceleration stress is very minimal. The USAF A-10 aircraft has been experimentally observed in flight and found to undergo sustained low G stress for several minutes with occasional excursions to +7Gz. We have simulated these A-10 profiles (Dr Kent Gillingham) on the USAF SAM centrifuge. The profiles were not as stressful as other aerial combat simulations, such as the F-4 simulation, and were not observed to have frequent dysrhythmias occur during the runs. In general, however, we certainly do see more dysrhythmias occur as the length of the acceleration increases. I have not broken down our data as yet to determine which types of dysrhythmia are most apt to occur as the length of exposure increases.

DR F L JACKSON (US)

Did you find any relationship between the type of dysrhythmia and the type of preconditioning exercise the pilots underwent - for example, the aerobic runners versus the anaerobic weightlifters?

AUTHOR

Yes, but the evidence is mainly anecdotal. We have had cases of aerobic conditioning (six miles per day, six days per week of jogging) who have shown sino-atrial block, with complete asystole for 15-20 seconds, after the G load has stopped. It is important to emphasize the importance of not overdoing exercise.

## ACCELERATIONS ET APTITUDE DES PILOTES D'AVIONS DE COMBAT.

par

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## RESUME

Le pilotage des avions de combat nécessite l'intégrité anatomique et fonctionnelle des grandes fonctions physiologiques du pilote. Du fait des évolutions de l'avion au cours du combat, c'est manifestement la fonction cardiovasculaire qui est la cible des facteurs de stress liés au vol. C'est par conséquent l'examen du coeur et des vaisseaux qui retient toute l'attention de l'expert au cours des visites d'aptitude des pilotes d'avions de combat à l'admission, mais surtout lors des visites révisionnelles.

Les performances des avions de la nouvelle génération donnent encore plus d'importance à ce problème.

En cas de doute, il est très souvent utile à l'expert de juger de l'intégrité fonctionnelle circulatoire au cours d'un test standardisé, reproductif et représentatif du stress cardiovasculaire subi par le pilote.

C'est en quoi les expertises sous facteur de charge, réalisées en centrifugeuse au Laboratoire, apportent un supplément indispensable d'informations au bilan hospitalier.

Au cours du test, les principaux paramètres cardiovasculaires sont enregistrés de même que le champ visuel est évalué. Par ailleurs, l'observation télévisée du sujet et l'enregistrement de la conversation permettent une appréciation du comportement général.

Certaines anomalies électrocardiographiques disparaissent sous accélérations, elles ne revêtent alors aucune gravité, d'autres, au contraire, subsistent ou même apparaissent. Elles sont d'autant plus inquiétantes qu'elles s'accompagnent de troubles fonctionnels (hypertension avec pincement de la différentielle, hypotension marquée avec rétrécissement du champ visuel, tachycardie avec effondrement du débit cardiaque...).

## INTRODUCTION

Le pilotage des avions de combat nécessite l'intégrité anatomique et fonctionnelle des grandes fonctions physiologiques du pilote. Cependant, du fait des évolutions de l'avion au cours du combat, c'est manifestement la fonction cardiovasculaire qui est la cible principale des facteurs de stress liés au vol. Par conséquent, l'examen du coeur et des vaisseaux retient particulièrement l'attention de l'expert au cours des visites d'aptitude des pilotes d'avions de combat à l'admission, mais surtout lors des visites révisionnelles. Toute réaction fonctionnelle cardiaque inadéquate, toute anomalie électrocardiographique importante, tout trouble circulatoire et toute cardiopathie entraîne irrémédiablement l'élimination. Les examens médicaux cliniques, électriques, radiologiques et biologiques, permettent le plus souvent de se prononcer sans trop d'hésitation. Mais, en cas de doute, en complément des examens médicaux, il est très souvent utile à l'expert de juger de l'intégrité fonctionnelle respiratoire et circulatoire au cours d'un test standardisé, reproductif et représentatif du stress respiratoire et cardiovasculaire subi par le pilote. Les performances des avions de combat de la nouvelle génération donnent encore plus d'importance à ce problème. C'est en quoi les expertises sous facteurs de charge (accélérations + Gz), réalisées en centrifugeuse au Laboratoire de Médecine Aérospatiale du C.E.V. apportent un supplément d'informations indispensable aux examens hospitaliers.

Ainsi sont justiciables de test en centrifugeuse, le pneumothorax à évolution spontanée ou opéré, les malaises en vol, les cardiopathies légères, les troubles hémodynamiques (hypo ou hypertension artérielle), les troubles de conduction, (blocs de branche) et les extrasystoles.

#### TECHNIQUE

##### Moyens matériels

Les accélérations longitudinales + Gz sont produites par la centrifugeuse Latécoère 260. Elle est constituée d'un axe vertical de rotation qui porte un bras horizontal de 6 mètres de long, à l'extrémité duquel une nacelle est fixée. La nacelle oscille librement dans le plan vertical. Ainsi l'accélération résultant de la composition du vecteur centrifuge créé par la rotation et du vecteur gravité est toujours perpendiculaire au plancher de la nacelle (Fig. 1). Cette accélération résultante normale au plancher s'exerce dans l'axe du dossier du siège sur lequel s'appuie le sujet testé.

L'installation de la nacelle comprend :

- un siège éjectable Martin Baker MK4 muni d'une gouttière latérale destinée à recevoir le bras gauche du sujet ;
- une caméra de télévision couleur, pointée sur la face du sujet ;
- un éclairage d'ambiance pour la télévision ;
- un appareil de plethysmographie par impédance électrique ;
- un brassard de prise de pression artérielle muni d'un dispositif de commande à distance ;
- une rampe semi circulaire de lampes pour le contrôle du champ visuel avec poignée de topage pour accuser la réception des signaux visuels.

##### Enregistrements physiologiques

Les paramètres physiologiques qui sont enregistrés pendant la durée de tout le test sont les suivants :

- l'électrocardiogramme ;
- la fréquence cardiaque ;
- la pression artérielle ;
- le volume d'éjection systolique ;
- le champ visuel périphérique sur un méridien.

L'électrocardiogramme est obtenu à partir de quatre électrodes collées sur la peau préalablement décapée. Deux électrodes sont placées dans la fosse sus épineuse droite et gauche, les deux autres en regard du triangle de Jean Louis PETIT (Fig. 2). Cette disposition permet d'obtenir les trois dérivations périphériques standards (D1 D2 D3). Elle minimise les perturbations dues au myogramme et les variations respiratoires de la ligne de base, elle offre un excellent rapport signal bruit. Enfin, elle laisse le thorax entièrement libre pour la mise en place des électrodes de pléthysmographie et pour le capteur de phonocardiographie.

Après amplification, les signaux électriques recueillis par les électrodes sont envoyés au moyen de contacts tournants vers les enregistreurs terminaux placés dans la cabine d'observation de la centrifugeuse et sur un oscilloscope cathodique à mémoire, placé devant le médecin responsable du test.

La fréquence cardiaque calculée sur trois cycles est fournie en continu par un compteur digital. Toutefois les valeurs figurant dans le rapport d'expertise sont calculées d'après le tracé de l'électrocardiogramme sur dix cycles cardiaques.

La pression artérielle systolique et diastolique est mesurée au moyen d'un brassard pneumatique dont les cycles de gonflage et de dégonflage sont assurés par un système électromécanique actionné directement depuis le poste de commande. On enregistre ainsi l'évolution dans le temps de la pression dans le brassard et les variations du pouls huméral détectées par un capteur de pression  $\pm 0,2$  kPa.

Le volume d'éjection systolique est mesuré par pléthysmographie par impédance électrique, technique non sanglante et utilisée au LAMAS depuis de nombreuses années.

Son principe est simple. Lorsqu'un segment corporel est parcouru par un courant électrique de haute fréquence les variations de volume liées aux variations circulatoires qui s'y produisent, entraînent des variations d'impédance électrique. Un courant de haute fréquence (100 kHz) faiblement volté, est injecté entre deux électrodes placées sur la peau, l'une à la base du cou (carotides), l'autre à un travers de main sous le mamelon gauche (région précordiale basse).

Ce courant circule entre les deux électrodes par les conducteurs offrant la résistance minimum à son passage (gros vaisseaux du tronc, aorte en particulier).

A toute variation d'impédance mesurée entre deux électrodes cutanées placées sur la manubriumsternal en regard de l'aorte correspond une variation de volume du segment aortique compris entre les électrodes et lui-même proportionnel au volume d'éjection systolique. Grâce à un dénouillement graphique proposé par KUBICEK et au repérage du temps systolique par un phonocardiogramme, il est possible d'apprécier le volume d'éjection et d'en déduire le débit aortique connaissant la fréquence cardiaque.

L'adjonction d'une troisième électrode permet par une commutation adéquate de corriger si besoin les variations liées au déplacement de l'aorte ascendante au cours des accélérations (Fig. 3).

Si une telle méthode ne permet pas de fournir des valeurs absolues de débit, elle est parfaitement utilisable pour évaluer les variations du débit. Elles sont exprimées en pourcentage par rapport à une valeur de repos.

Le test visuel permet d'explorer la vision périphérique sur un méridien. A cet effet, 16 petites lampes blanches sont disposées tous les dix degrés sur une rampe semi-circulaire placée dans un plan horizontal passant par les yeux du sujet. Les deux lampes extérieures lorsqu'elles sont vues correspondent à un champ visuel de 180°.

A partir du poste de surveillance médicale, un boîtier de commande assure de façon aléatoire l'allumage de la lampe droite ou gauche la plus extrême. Le sujet doit maintenir une vision centrale et éteindre les lampes à l'aide d'un bouton poussoir. Le temps mis pour cette extinction est numérisé et enregistré sur une imprimante. La non-extinction d'une lampe est considérée comme une amputation du champ visuel de 20° et l'allumage est alors commuté sur le jeu de lampes suivant.

Le dispositif des lampes est répété sur le boîtier de commande devant les yeux du médecin (Fig. 4).

Un tel système permet non seulement d'explorer le champ visuel mais encore d'apprécier le temps de réponse (temps de réaction) au stimulus lumineux (le temps moyen d'allumage des lampes est de une seconde environ).

#### Protocole

Après mise en place des électrodes et du brassard le sujet est installé sans protection anti G sur le siège éjectable Martin Baker où il est soigneusement sanglé. Son bras gauche muni d'un brassard est placé en position horizontale dans la gouttière latérale située à la hauteur du cœur. Le bouton poussoir d'extinction des lampes est tenu dans la main droite. Un casque d'écoute et un laryngophone sont mis en place pour permettre la conversation au cours du test. Les branchements sont alors effectués et les différents enregistreurs mis en route.

Une fois la nacelle fermée et l'obscurité faite, il est laissé quelques minutes au sujet pour se familiariser avec le test de champ visuel.

L'examen comprend deux lancements de la centrifugeuse par moteur électrique.

Le premier lancement comporte trois paliers successifs de 30 secondes à +3, +4 et +5 Gz. Le taux d'établissement est de 0,5 g/s pour chacun des paliers. Cinq minutes après, un second lancement est effectué directement jusqu'à +5 Gz appliqués pendant 20 à 25 secondes.

Dans certains cas un autre lancement peut être réalisé jusqu'à +5 ou +6 Gz avec un sujet équipé d'un pantalon anti g.

Tous les paramètres physiologiques recueillis sont enregistrés en continu pour chaque lancement depuis 5 minutes avant le départ de la centrifugeuse jusqu'à 5 minutes après son arrêt.

Seule la pression artérielle est mesurée avant le départ, pendant les paliers, à l'arrêt et 5 minutes après.

Pendant tout le test, une surveillance continue de chaque sujet est assurée par télévision doublée sur magnétoscope et par liaison radiophonique avec le médecin responsable (Fig. 4).

En outre, un calculateur fournit par affichage numérique les indications physiologiques suivantes :

- la valeur d'un indice proportionnel au débit aortique ;
- la valeur de la fréquence cardiaque moyenne.

Un dispositif de sécurité permettant l'arrêt immédiat de la centrifugeuse est placé sur le pupitre du médecin.

A la fin du test un rapport, confidentiel médical, est envoyé à l'expert. Dans ce rapport est fait état des impressions subjectives ressenties par le patient (malaise, voile gris ou noir) de son comportement général durant le lancement (mimiques, demande d'arrêt) et des résultats objectifs apportés par les enregistrements physiologiques (fréquence cardiaque, électrocardiogramme, pression artérielle, volume d'éjection systolique et débit cardiaque, champ visuel et temps de réaction). Une photocopie des différents tracés des paramètres cardiovasculaires est joint à ce rapport.

## RESULTATS

Notre étude porte sur 30 dossiers concernant 27 pilotes de chasse en cours de formation ou confirmés. Elle couvre ces trois dernières années. Elle comprend 5 cas de pneumothorax cicatrisés à évolution spontanée ou opérés (sujets 1 à 5), 10 cas de malaises en vol (sujets 6 à 15) 2 cas de troubles tensionnels (sujets 16 et 17) 2 cas de cardiopathies légères : petites insuffisances aortiques (sujets 18 et 19), 8 cas de troubles du rythme : 4 cas de trouble de la conduction (sujet 20 à 23) et 4 cas d'extrasystoles (sujets 24 à 27).

Trois sujets ont été revus. Il s'agit du sujet 10 (malaises en vol) du sujet 20 (bloc auriculo-ventriculaire du premier degré) et du sujet 26 (extrasystoles permanentes).

16 sujets n'ont présenté lors de ces tests en centrifugeuse aucun trouble particulier ni signe objectif d'intolérance cardiovasculaire. Par contre, dans les autres cas, des critères objectifs de défaillance ont été mis en évidence. Il peut s'agir d'impressions subjectives : voile gris ou noir, de malaises indéterminés, c'est le cas le plus fréquent (6 sujets = 22 p. cent) accompagnés de perturbations hémodynamiques : pression artérielle systolique et diastolique basse ou inchangée (3 sujets = 11 p. cent) pincement de la différentielle (1 sujet = 4 p. cent) fréquence cardiaque trop accélérée ou trop basse (4 sujets = 15 p. cent) et de la persistance d'anomalies électrocardiographiques parfois aggravées : troubles de la conduction (2 sujets = 7 p. cent) ou extrasystoles permanentes (2 sujets = 7 p. cent).

## DISCUSSION

Une analyse plus détaillée de nos différents cas apporte les renseignements nécessaires pour justifier l'emploi de la centrifugeuse et les décisions d'aptitude qui en ont découlé.

Dans les conditions physiologiques normales la base et le sommet du poumon ont une ventilation différente. Au sommet le vide pleural étant plus important, les alvéoles sont plus ouvertes au cours de l'inspiration et se collabent moins bien au cours de l'expiration qu'au niveau de la base. Il s'ensuit une relative distension du sommet par rapport à la base du poumon. Sous facteur de charge + Gz la force d'inertie attire le poumon vers le bas et accentue cette distension. On peut donc concevoir que la rupture de petites bulles d'air emprisonnées au niveau du cortex apical pourrait survenir et être cause de récurrence de pneumothorax. En ce qui nous concerne nous n'avons jamais constaté de troubles respiratoires ou de récurrences chez nos cinq pilotes qui, tous, avaient bénéficié d'une pleuroctomie à la GAENSLER après leur pneumothorax. De même aucune réaction cardio-vasculaire anormale n'a été observée. Une radiographie de contrôle en position d'expiration, et une épreuve au caisson à 10.000 mètres avec oxygène ont confirmé ces constatations. Ces 5 pilotes ont donc été reconnus aptes pilotes de chasse sans restriction.

Le problème des malaises en vol est sûrement un des chapitres de la médecine aéronautique le plus préoccupant et le plus fréquent mais qui laisse bien souvent le médecin dans l'incertitude sur les étiologies possibles.

Les accélérations ont été très souvent incriminées. D'une façon générale deux cas peuvent être envisagés, soit les malaises ne sont pas déclenchés par les accélérations, soit elles sont directement en cause.

1. - Sur nos 10 pilotes, trois d'entre eux ont parfaitement bien toléré les lancements en centrifugeuse, tant du point de vue subjectif qu'objectif. Leur comportement hémodynamique est parfaitement normal et il ne paraît pas possible d'accuser les accélérations comme cause unique du malaise survenu au cours d'une évolution en vol. Le facteur déclenchant doit être recherché ailleurs (facteur psychologique ou social, fatigue passagère, etc...). Après surveillance, ces pilotes ont été maintenus aptes pilote de chasse.

2. - Il n'en est pas de même dans les 7 autres cas où les malaises accompagnent les accélérations.

a) Les malaises trouvent leur explication dans un trouble hémodynamique induit par les accélérations. Cette défaillance hémodynamique peut parfois être spectaculaire : pression artérielle systolique et diastolique trop basse, rarement supérieure à 13/9 (sujets 10 et 12), 11/5 à + 5 Gz pour l'un deux ; pincement de la différentielle (sujet 8 : 17,5/16 à + 5 Gz), tachycardie supérieure à 150 coups minute (sujets 9 et 10), bradycardie (sujets 8 et 14). Bien souvent ces symptômes s'accompagnent du cortège habituel de signes subjectifs (voiles, sensations désagréables, etc...). Il convient cependant de signaler que nous n'avons jamais observé de troubles de l'électrocardiogramme.

b) A l'opposé, dans certains cas, on ne trouve aucune explication cardio-vasculaire à l'apparition des malaises. Cependant, les accélérations déclenchent les mêmes troubles : perte du champ visuel objectivée par le test (sujets 11 et 15), névralgies occipito-cervicales (sujet 11). Dans ce cas on est le plus souvent orienté vers une perte de motivation que vers une inadaptation cardio-vasculaire aux accélérations.

Quoi qu'il en soit, ces pilotes ont été reclassés aptes pilotes de transport. Une exception a été faite pour le sujet n° 10 qui a été vu deux fois et pour lequel une décision définitive n'a pas été prise.

Les sujets 16 et 17 présentent des cas un peu particuliers. Le premier, jeune élève pilote était affligé d'une hypotension qualifiée de labile. Au cours du passage en centrifugeuse avec et sans pantalon anti g malgré une pression artérielle assez basse nous n'avons jamais constaté de signes de défaillance cardio-vasculaire pour une accélération de 5 Gz, pendant une minute. Le deuxième, pilote confirmé, âgé de 39 ans, à la suite d'une néphropathie interstitielle avait une hypertension artérielle modérée, réduite par la prise journalière d'un demi comprimé d'acébutolol (bêta-bloquant). Là encore, la tolérance cardio-vasculaire aux accélérations était excellente. En conséquence, son aptitude pilote de chasse a été maintenue pour 6 mois avec réhospitalisation à l'issue.

Le règlement stipule que toute cardiopathie entraîne l'inaptitude pilote de chasse. Malgré l'excellente tolérance hémodynamique sous accélérations manifestée par les pilotes 18 et 19, affectés d'une légère insuffisance aortique, l'inaptitude devait donc s'imposer. Cependant devant ces résultats favorables, l'expert hospitalier a proposé la demande d'une dérogation pour un an sous réserve d'une expertise annuelle avec bilan complet.

Les troubles du rythme, blocs auriculo-ventriculaire ou extrasystoles sont d'observation banale au cours des accélérations + Gz soutenues. Le problème devient plus complexe lorsque ces anomalies existent ou apparaissent au cours de la vie professionnelle d'un pilote. C'est ainsi que l'on a découvert un bloc auriculo-ventriculaire du premier degré, un bloc de branche droit, un bloc auriculo-ventriculaire du deuxième degré type Luciani-Wenckebach (MOBITZ I) et une fibrillation auriculaire consécutive à une erreur diététique. Les épreuves en centrifugeuse ont montré une bonne tolérance cardio-vasculaire aux accélérations et aucune altération des tracés électrocardiographiques. Cependant, l'un d'eux a été déclaré inapte à tout emploi dans le personnel navigant car il s'agissait d'une visite d'admission. Les autres bénéficient d'une aptitude temporaire reconduite lorsque les résultats des visites de contrôle sont satisfaisants.

La permanence d'extrasystoles ne paraît pas être d'un bon pronostic pour la carrière d'un pilote de chasse. Lorsqu'il s'agit d'un jeune élève candidat pilote, cette anomalie électrocardiographique entraîne son élimination (inaptitude à tout emploi dans le personnel navigant). C'est ce qui est advenu à l'un de nos malades présentant des extrasystoles ventriculaires monomorphes quadrigémînés et nombreuses qui persistaient sous accélérations. La décision est moins rigoureuse lorsqu'il s'agit d'un pilote ancien. Ce fut le cas d'un pilote plus confirmé dont l'électrocardiogramme comporte des extrasystoles permanentes mais chez lequel on n'a jamais observé de défaillance cardio-vasculaire, en particulier, d'effondrement du volume d'éjection systolique ou de pincement de la pression artérielle différentielle, ni d'aggravation du trouble du rythme sous accélérations.

Cependant, un reclassement dans le transport a été proposé. Le plus souvent, ces extrasystoles coexistent sur un fond de vagotonie et ne semblent pas affecter gravement les réactions cardiaques et vasculaires physiologiques déclenchées normalement par les accélérations.

#### CONCLUSION

Le Laboratoire de Médecine Aérospatiale du Centre d'Essais en Vol, équipé d'une centrifugeuse et de moyens de mesures autorisant une exploration fonctionnelle cardiovasculaire adéquate sous accélérations, a testé au cours de ces trois dernières années 27 pilotes de chasse. Ces pilotes étaient affectés de troubles vasculaires, cardiaques ou respiratoires, ou avaient manifesté des malaises en vol au cours d'accélérations. Ces examens ont permis d'apporter une contribution capitale à l'expert chargé de prendre une décision d'aptitude. Il est en effet possible de suivre sur le plan psychologique et physiologique (surtout cardiovasculaire) le pilote dans des conditions de simulation reproduisant au mieux l'agression rencontrée dans sa vie professionnelle. Ces épreuves répétées à volonté permettent d'analyser les évolutions transitoires favorables ou défavorables, et de détecter les effets éventuels du vieillissement du patient.

Elles permettront peut être dans l'avenir de tester la tolérance à certaines thérapeutiques.

Cependant, la mise en oeuvre de ces épreuves réalise une charge lourde en temps, en matériel et personnel, qui en freine leur emploi plus systématisé.

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- Travail du Laboratoire de Médecine Aérospatiale du Centre d'Essais en Vol de Brétigny-sur-Orge et du Service de Médecine Aéronautique de l'Hôpital d'Instruction des Armées D. Larrey Versailles.

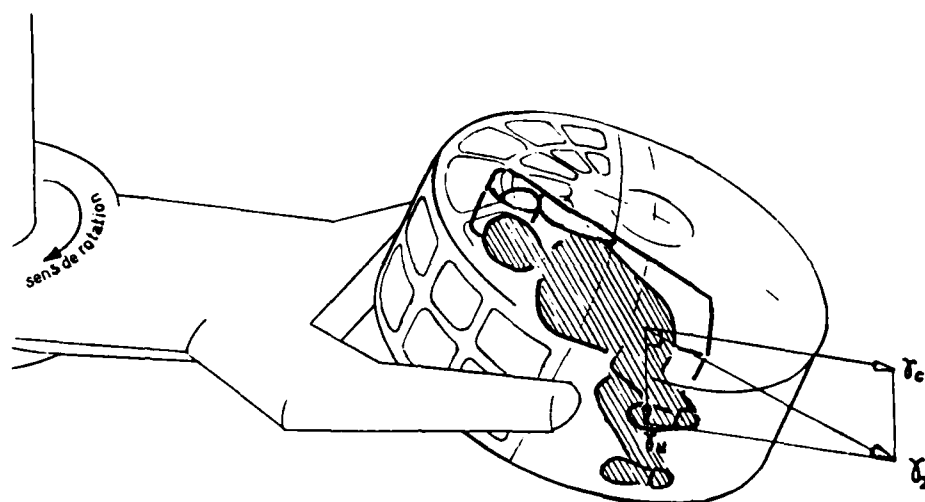
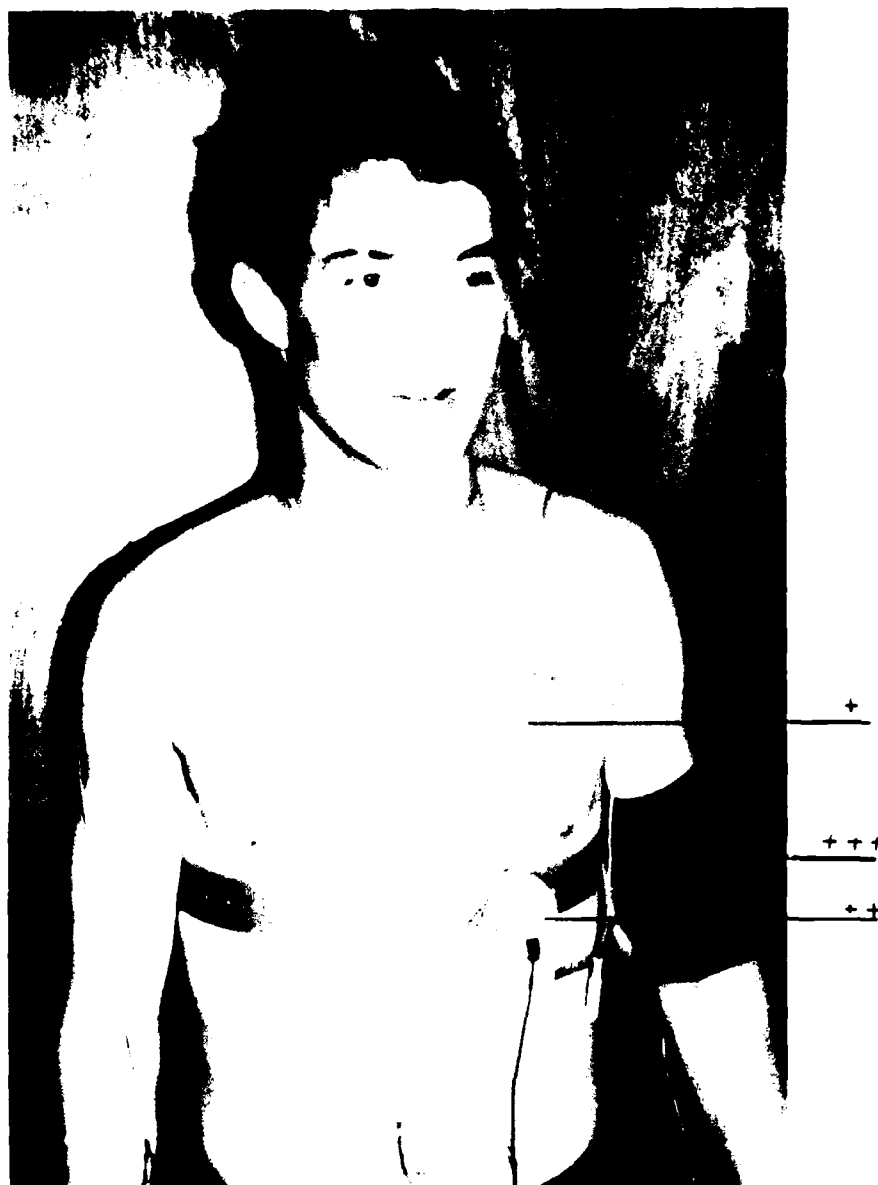


Fig.1 Composition des vecteurs d'accélération  
sur un sujet assis dans la centrifugeuse



Figure 2

Positions adoptées pour les électrodes  
de l'électrocardiographe



Sujet équipé :

- + des électrodes de pléthysmographie électrique,
- ++ du capteur de phonocardiographe maintenu par une bande élastique,
- +++ du brassard de prise de pression artérielle au bras gauche.

Figure 3



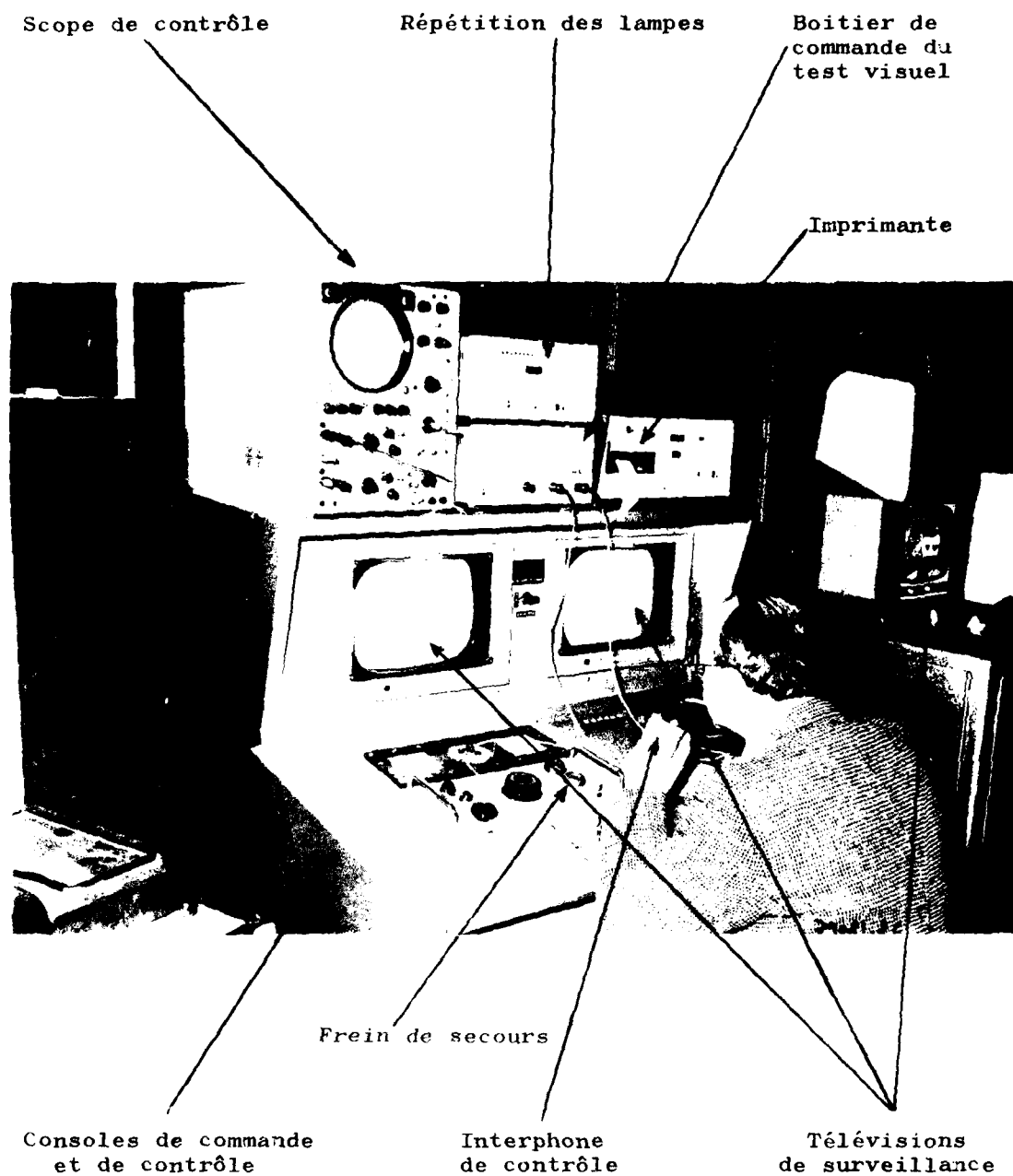


Figure 4

## DISCUSSION

DR J E WHINNERY (US)

1. Are there fighter aircraft in the French Air Force which have the requirement for breathing 100% oxygen throughout flight (including aerial combat and manoeuvres)?
2. What type and frequency of 'extrasystoles' such as you described, particularly the ventricular extrasystoles, are considered benign and compatible with continued French fighter aircraft flying status? Perhaps put in a better way, what types are specifically disqualifying in the ventricular extrasystole category?

AUTHOR

1. There is no particular French regulation concerning the breathing of 100% oxygen. The regulation followed is almost the same as that of the F.A.R.
2. In the entrance examination for flying personnel, the existence of 'extrasystoles' is disqualifying. On the otherhand, in the case of a trained pilot, where extrasystoles exist (including those arising under acceleration) without any other cardiovascular abnormality, reclassification as a transport pilot may be contemplated.

DR D R JONES (US)

Can you give any follow-up data on those aircrew whom you treated for motion sickness?

AUTHOR

We have had three years follow-up without problem. Of the three pilots considered fit for fighter aircraft, their airsickness, which was not due to acceleration stress, did not cause them further difficulty. Seven pilots were recategorised to transport aircraft (their airsickness was related to acceleration stress) and one of them has had continuing problems which are the subject of current review.

DR J CLEMENT (BE)

You have illustrated a case of quadrigeminal extrasystole. What decision would you have reached if the patient in question had been a test pilot?

AUTHOR

In my opinion, in such a case the pilot should be retained on full flying status. I believe it is necessary to investigate the origin of his extrasystoles and take a full medical history. In particular it is important to exclude a reduction in stroke volume or pulse pressure and any increase in rhythm disturbance under acceleration.

EXPERIENCE WITH HIGHLY SELECTIVE  
SCREENING TECHNIQUES FOR ACCELERATION STRESS DUTY

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High-speed, low-level mission profiles performed in highly maneuverable aircraft place rigorous physical stresses on aircrewmembers. The potential for unconventional maneuvers in control-configured (or vectored-force) six degree-of-freedom aircraft further accentuate the problem. The stresses exceed those normally encountered in conventional missions and therefore suggest the development of more rigorous screening techniques to select crewmembers for high stress missions. Such techniques should only be applied if evidence indicates inadequacies in mission effectiveness or safety which are attributable to the use of current aircrew screening techniques. This is true since more selective screening requires a greater investment, eliminates a portion of previously successful candidates, and should demand evidence that successful candidates will perform significantly better than unsuccessful ones. In considering these issues it is enlightening to review previous experience at the Air Force Aerospace Medical Research Laboratory (AFAMRL) in the application of more stringent screening standards as applied to an active duty USAF population.

#### INTRODUCTION

The mission of the Biomechanical Protection Branch (BBP) of AFAMRL is to develop protection technology for mechanical stress environments, to apply biomechanical technology in the development of design criteria for aircrew restraint and emergency escape systems, and to determine human biodynamic impact response using current or proposed protection systems. To accomplish these goals, AFAMRL/BBP, a part of its ongoing research efforts, conducts impact acceleration tests in the three cardinal axes utilizing human volunteer subjects. Facilities utilized include the Vertical Deceleration Tower (for  $G_z$  exposures) and the Horizontal Decelerator and Impulse Accelerator sleds (for  $G_x$  and  $G_y$  exposures). Data is obtained by means of high-speed films of the event, load cells mounted in the seat and restraint system and accelerometer packs mounted on the subject. These tests are conducted in accordance with the guidelines for human experimentation established in Air Force Regulation 169-3. A detailed Human Use Research Protocol prepared by the investigators in advance of each proposed test program is presented to and subject to the approval of the AFAMRL Human Use Review Committee. This committee, which is composed of USAF flight surgeons, safety officers, civilian researchers, a nurse, a chaplain, and a legal consultant, oversees all AFAMRL experiments in which humans are utilized. Through the chain of command, ultimately, the USAF Surgeon General must approve all "at-risk" human experimentation conducted at AFAMRL. Recent impact test programs conducted at BBP include the evaluation of a proposed modified F/FB-111 crew seat and restraint system (ref. 2) and the initial  $-G_x$  investigation of the concept of dynamic preload (ref. 9).

A group of approximately twenty-five active duty Air Force officers and enlisted personnel participate as subjects in this impact research. These individuals comprise the Impact Acceleration Stress Panel which is medically supervised by a USAF flight surgeon designated as the Impact Panel Physician. The subjects are derived from the large population of active duty USAF personnel permanently assigned to AFAMRL and other USAF organizations at Wright-Patterson Air Force Base. Their primary duty assignments are other than participating as volunteer subjects. Although a panel of "professional" volunteer subjects is utilized in impact experiments elsewhere in the United States (ref. 11), we believe that an individual's primary duty assignment must be separate and distinct from his participation as a research subject as a prerequisite for such participation being truly voluntary on a continuing basis. Informed consent of all volunteers is initially obtained and documented for each test program following a subject briefing at which the purpose of the proposed research is explained by the principal investigator, the potential adverse effects (medical risks) are detailed by the medical investigator, and all subject questions are addressed. Ongoing consent is assured by repeatedly emphasizing to all subjects that they are free to withdraw from participation at any time without prejudice and, during each impact exposure, by providing the subject with a finger-operated microswitch which he must actively depress throughout the pretest phase for the impact to occur. An on-site physician designated as the medical monitor is present for each human impact exposure to insure subject safety. The monitor has the capability to abort the test at any time prior to impact (by means of a finger-operated switch) for any circumstance he believes would place the subject at undue risk and is able to provide emergency medical care in the unlikely event of a misadventure.

#### CURRENT CANDIDATE SCREENING PROCEDURE

In order to qualify for participation in impact acceleration stress experiments, candidates must successfully complete an intensive medical evaluation. The goal of this evaluation is to eliminate from consideration not only those individuals with clearly disqualifying physical defects (e.g., inguinal hernia, significant cardiac murmur), but also those candidates who may have more subtle physical defects of the vertebral column, since we believe that all of these candidates, by virtue of these defects, may possibly be predisposed to injury in the impact environment. Admittedly, this philosophy results in a panel of "supra-normal" individuals; however, we believe that such an approach is necessary to insure subject safety.

Due to the large number of active duty personnel assigned to Wright-Patterson Air Force Base, recruiting a sufficient number of volunteers has not been a problem. In fact, a waiting list of individuals who have expressed an interest in becoming panel members is maintained. As positions on the Impact Panel become available, generally by panel members leaving military service or moving to new

duty stations, candidates on the waiting list are offered a screening interview with the Panel Physician. During this interview, the physician reviews the candidate's medical records with a view towards eliminating those individuals who would not be suitable impact subjects on the basis of their past medical history. These would include candidates with, e.g., a prior history of chronic neck or back problems, loss of consciousness, a major orthopedic procedure (e.g., knee reconstruction), or idiopathic hematuria. Following this screening, the candidates remaining are briefed, in general terms, regarding the impact test program and the potential medical risks of participation, are taken on a tour of the impact test facilities, and are shown films of prior human impact exposures, so that they may fully appreciate the severity of the inertial response to impact accelerations.

At this point, the remaining prospective subjects are offered a medical evaluation, as outlined in Table 1 and as detailed in the following paragraphs. Note that all subjects are required to undergo, not only an initial qualification evaluation, but also an annual recertification exam as well as a termination evaluation when leaving the panel. The current requirements for each type of medical evaluation are shown in Table 1.

<u>Requirement</u>	<u>Examination</u>		
	<u>Initial</u>	<u>Annual</u>	<u>Termination</u>
History and Physical Examination	x	x	x
Laboratory Screen	x	x	x
Electrocardiogram (EKG)	x	x	x
Pulmonary Function Tests (PFTs)	x		x
Electroencephalogram (EEG)	x		x
X-rays (skull, chest, spine)	x		x
Treadmill Stress Test	x		

Table 1. Medical Evaluation Requirements for Impact Acceleration Stress Duty

1. A thorough physical examination by a USAF flight surgeon, generally the Panel Physician, is accomplished. The purpose of this exam is to identify and eliminate from consideration those individuals with positive physical findings which would predispose them to injury in the impact environment. For example, individuals with dental problems such as poor dental hygiene with missing teeth, malocclusion, or significant bridgework do not have adequate dental structure to support a bite-block and mouth-mounted accelerometer pack, which is required to measure head acceleration during impact. Those with umbilical or inguinal hernias would be at risk for incarceration if exposed to impact, due to the increased intra-abdominal pressure which occurs during these accelerations. Candidates with a noticeable scoliosis or a pronounced lumbar lordosis are considered to be at higher risk for vertebral column injury in the impact environment. All of these individuals would not be suitable candidates for impact acceleration exposure and all would be eliminated from further consideration. The remainder of the physical examination consists of sitting and standing blood pressures, a pure tone audiogram, and a visual acuity evaluation. Refraction and tonometry are generally not performed. Female candidates undergo a pelvic examination by a gynecologist to rule out gynecologic contraindications to participation.

2. The laboratory screen includes hematocrit, platelet count, prothrombin time (PT), partial thromboplastin time (PTT), RPR, and urinalysis, including appearance, specific gravity, pH, blood, protein, glucose, bilirubin, and microscopic evaluation of the urinary sediment. It is reasonable to insure that individuals about to be exposed to experimental conditions in which mild bruising is an anticipated and acceptable risk have a normal coagulation profile. In an extreme case, e.g., a candidate with unrecognized idiopathic thrombocytopenic purpura and a platelet count less than 20,000, would certainly be at increased risk for intracranial hemorrhage in the impact environment. In addition to the above laboratory tests, female candidates must have a negative pregnancy test documented.

3. A standard 12-lead electrocardiogram (EKG) is performed. Individuals with significant cardiac or electrocardiographic abnormalities are referred to a cardiologist for consultation and further evaluation (e.g., vector cardiogram or echocardiogram), as required.

4. Pulmonary function studies, including determinations of forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and maximum mid-expiratory flow rate (MMEFR) are performed. Since subjects, in some restraint harness configurations, experience a restriction to inspiratory effort, a candidate with a baseline restrictive deficit, e.g., as indicated by a decreased FVC, would be subject to higher risk in the impact environment than would a normal candidate and would, therefore, not be a suitable subject for impact testing.

5. An electroencephalogram (EEG) is accomplished and interpreted by a neurologist in order to exclude those with latent seizure activity or other EEG abnormalities and to obtain a baseline for comparison, since the potential for head trauma exists in this experimentation. The EEG is of some diagnostic value in assessing brain trauma, particularly in assessing cerebral contusions and lacerations as well as subdural hematomas. This examination is of less value in assessing cerebral concussions.

6. Notwithstanding clear evidence which indicates that the exercise stress test is of limited predictive value in the detection of coronary artery disease in asymptomatic individuals (ref. 8), all candidates are required to perform a treadmill exercise stress test (Balke protocol). The significant cardiopulmonary work load imposed by this test permits evaluation of the cardiac rhythm at increased heart rates, which simulates the pre-impact test phase when subject anxiety is present and there is a significant tachycardia. Maximum oxygen consumption is computed and evaluated for each candidate. Test results are discussed with a cardiology consultant, as indicated.

7. X-ray requirements include the following fourteen films: skull (AP/lateral), chest (PA/lateral), and spine (odontoid process, AP/lateral cervical spine, AP/lateral thoracic spine, and AP/lateral/coned-down lateral/right and left oblique lumbosacral spine). Individuals who demonstrate radiographic evidence of previous vertebral column trauma and/or congenital anomalies may be predisposed to injury in the impact environment. For this reason, disqualifying radiographic findings include (among others):

Vertebral Compression Fractures  
Disc Space Narrowing  
Spondylolisthesis  
Extreme Lumbar Lordosis  
Schmorl's Nodes (two or more)  
Spondylolysis  
Degenerative Spine Disease (spurring, bridging)

All x-rays are reviewed with a radiology consultant as well as an orthopedic consultant, as required.

The final step in the candidate qualification process is a review of all the data derived from the medical evaluation by the Panel Physician and, in turn, by the physician Chairman of the HURC. Additional tests or consultations are obtained, if indicated. We believe that this initial medical evaluation is sufficiently stringent to eliminate as potential subjects all individuals with physical defects or anomalies which would place them at a higher risk for injury during impact accelerations than those individuals with no such defects. To date, no subject has been jeopardized as a result of a deficiency in this screening technique. Our evaluation is more rigorous than a routine USAF flying physical examination, since the latter does not require pulmonary function tests, an electroencephalogram, an exercise stress test, or skull/spine x-rays. Nonetheless, the medical standards outlined in Air Force Regulation 160-43 are used as guidelines in all evaluations.

#### RETROSPECTIVE ANALYSIS OF UNSUCCESSFUL CANDIDATE DATA

A retrospective analysis of the medical evaluations of unsuccessful applicants for Acceleration Stress Duty (ASD) between 1 Jan 77 and 31 Dec 79 was conducted with a view toward improving the current screening procedure. This candidate group included applicants for both the Sustained Acceleration Stress Panel and the Impact Acceleration Stress Panel at AFAMRL. During this period of time, 134 applicants were processed; 63 candidates were successful and 71 were not successful. The reasons for which members of this latter group were not successful are listed in Table 2. Those who voluntarily withdrew did so for personal reasons or because they were preparing to change duty assignments at the time their applications were reviewed.

<u>Basis for Disqualification</u>	<u>Number Disqualified</u>
Physician Screening	8
Medical Evaluation Data	45
Voluntary Withdrawal	18

Table 2. Reasons for Disqualification of Unsuccessful Candidates (1 Jan 77 - 31 Dec 79)

Of the 45 candidates who were medically disqualified, 42 were eliminated on the basis of radiographic findings related to the vertebral column and only three were eliminated on the basis of, e.g., EEG or other abnormalities. This high incidence of radiographic spinal abnormalities, at first glance, is surprising in a population of asymptomatic individuals with, ostensibly, no past history of significant neck or back trauma. However, note that the type of individual who applies for Impact Acceleration Stress Duty is typically an adventuresome sort. Past candidates have engaged in such activities as race car driving, boxing, bowling, football, skiing, and sky diving. One individual's interest in our research was stimulated by his involvement in an automobile accident in which he experienced a significant impact. In light of this data, the high frequency of positive radiographic findings is less startling.

A review of the entire screening x-ray series of the 42 candidates who were disqualified on a radiographic basis revealed three major defect categories and a distribution of specific defects throughout the cervical, thoracic, and lumbosacral spine as shown in Table 3. Thus, there were 92 disqualifying defects among 42 unsuccessful candidates. Some prospective subjects had multiple and different disqualifying defects evident on the same x-ray film. Others had multiple and sometimes different defects on multiple (at times as many as 5) x-rays.

Since one of the tacit principles of clinical and particularly of research medicine is to minimize human radiation exposure, we correlated each disqualifying defect with the x-ray which revealed that defect, in an attempt to determine the relative "yields" of significant defects for each particular type of x-ray. The results of this effort appear in Table 4. (The lateral chest x-ray and oblique x-rays of the lumbosacral spine have recently been added to the AFAMRL screening protocol and, therefore, do not appear in Table 4.) A relatively small number of disqualifications occurred on the basis of AP spine films. All were related to scolioses. (Some of these candidates had other disqualifying defects on other x-rays as well.) We believe that all cases of scoliosis should be considered on an individual basis, as some candidates with mild scolioses (less than 10% curvature) are suitable for ASD. Clearly the x-rays which most frequently revealed disqualifying defects were the lateral thoracic, lumbosacral, and cervical spine films. Sixty-four of the eighty-two x-rays which revealed disqualifying defects were lateral spine films. Thirty-nine of the forty-two candidates disqualified on the basis of radiographic findings were eliminated on the basis of one or more of these three lateral spine films. Therefore, these data indicate that a large percentage of those candidates who will be eliminated for radiographic reasons may be adequately screened by three lateral spine films, if "wet readings" of these films are provided during the radiographic screening.

Thus, as a result of this retrospective analysis of unsuccessful candidate data, our initial medical evaluation screening procedure has been modified in two respects. First, since 42 of the 45 candidate eliminations during the medical evaluation were on the basis of x-rays, applicants are currently radiographically screened immediately following completion of the history and physical examination and prior to all other elements of the medical evaluation. Second, since 39 of the 42 candidates disqualified for radiographic defects were eliminated on the basis of the lateral spine films, all candidates are currently "pre-screened" by first obtaining and reviewing these three films. If no abnormalities are noted, then the remaining required x-rays are accomplished. However, if disqualifying radiographic abnormalities are noted, then no further x-rays or other elements of the medical evaluation are pursued. Since adopting these modifications on 1 Jan 80, several candidates have been disqualified due to radiographic defects diagnosed with less than a full complement of screening x-rays.

Radiographic Abnormality	Region of Spinal Involvement			Total
	Cervical	Thoracic	Lumbosacral	
Trauma-Related				
Disc Space Narrowing	8	5	2	15
Loss of Anterior Vertebral Height	0	8	2	10
Loss of Posterior Vertebral Height	0	1	2	3
Schmorl's Nodes (two or more)	0	18*	7*	19
"Fish" Vertebrae	0	0	1	1
Degenerative Disease				
Anterior Bridging	1	4	1	6
Anterior Lipping	0	5	0	5
Anterior Osteophyte Formation	4	0	0	4
Spondylosis	1	0	0	1
Curvature/Alignment				
Marked Kyphosis	-	2	-	2
Marked Lordosis	0	-	6	6
Compound Lordosis	8	-	0	8
Significant Scoliosis	0	7**	5**	7
Spondylolisthesis	0	0	4	4
Abnormal Vertebral Alignment	1	0	0	1
Total Number of Abnormalities				92

\*Six abnormalities involved both thoracic and lumbosacral spine.

\*\*Five abnormalities involved both thoracic and lumbosacral spine.

Table 3. Types and Distribution of Disqualifying Radiographic Defects (1 Jan 77 - 31 Dec 79)

Type of X-ray	Number of X-rays Revealing Disqualifying Defects
T-spine (lateral)	25
LS-spine (lateral or coned-down lateral)	21
C-spine (lateral)	18
T-spine (AP)	8
LS-spine (AP)	5
C-spine (AP)	3
Odontoid	1
Chest (PA)	1
Total	82

Table 4. Numbers of Disqualifying Defects Indicated by Specific X-rays (1 Jan 77 - 31 Dec 79)

#### DISCUSSION OF SPECIFIC RADIOGRAPHIC FINDINGS

Schmorl's or cartilaginous nodes are intervertebral disc herniations into adjacent vertebral bodies (ref. 10). When Schmorl initially investigated cadaver spines, he found evidence of this end-plate disruption and nuclear prolapse in 38% of 3000 specimens examined. Wissing later observed radiographic evidence of Schmorl's nodes in 13.5% of over 400 x-ray series. In a recent study of 50 cadaver slab radiographs of the thoracolumbar spine, Hilton (ref. 7) found at least one Schmorl's node in 76% of the cases. Minimum end-plate displacements of one millimeter are required to be detected radiographically (ref. 6). On x-ray, the herniated disc material initially appears as a poorly defined, localized, radiolucent depression along the vertebral end-plate. Later, it may extend deeper into the vertebral body substance and develop an osseous boundary. This localized radiolucency and sclerotic boundary is pathognomonic of a Schmorl's node (ref. 4). These nodes occur more frequently in whites, are most frequently seen in teenage males, frequently involve several vertebral bodies, and occur primarily in the lower thoracic and upper lumbar vertebral bodies (ref. 1,4). Individuals with these lesions are often asymptomatic, but aching pain and tenderness to palpation at the affected level may be present (ref. 4). When these end-plate lesions arise in adolescence, they may predispose the thoracolumbar spine to associated intervertebral disc degeneration in later life (ref. 7).

Most authors (ref. 1,4,10) agree that Schmorl's nodes are precipitated by trauma (perhaps by merely the repetitive trauma of daily ordinary stresses) superimposed upon an underlying congenital defect in chondrification where blood vessels penetrate the cartilaginous end-plate. Metabolic and neoplastic disorders and degenerative disc disease have also been cited as other processes which may be causative in Schmorl's node formation by weakening the cartilaginous end-plate or the vertebral body (ref. 10).

However, there does not appear to be an association between Schmorl's nodes and osteoporosis (ref. 1). Since the etiology of cartilaginous nodes seems to be trauma-related, we do not consider it reasonable to expose individuals with these defects to the additional stress of spinal loading which occurs during impact accelerations. We, therefore, have elected to eliminate from consideration all candidates with radiographic evidence of two or more Schmorl's nodes.

These end-plate lesions should not be confused with so called "fish" vertebrae, which occur when diffuse processes such as osteoporosis or osteomalacia weaken the vertebral body, allowing the intervertebral disc to exert expansile pressure on the bone and resulting in arch-like indentations on the bony contour (ref. 10). Candidates with this x-ray finding are not suitable subjects. However, the differential diagnosis also includes individuals with a normal so-called "Cupid's bow" contour of the lower lumbar vertebrae. The inferior end-plates of L3, L4, L5 frequently have paired parasagittal concavities on AP projection. On lateral x-ray, these contours are superimposed posteriorly. In one x-ray series of 200 patients, 63% had at least one lower lumbar vertebra with a Cupid's bow contour (ref. 3). Candidates with this radiographic finding are considered normal variants.

Spondylolysis, a pars interarticularis defect which occurs with or without spondylolisthesis, has a strong hereditary basis, can be an asymptomatic finding, and occurs in approximately 6% of the white U.S. population. Since it is considered to be a fatigue or stress fracture secondary to repetitive trauma, which may be unrecognized (ref. 4), we do not accept applicants with this finding. The congenital anomalies of spina bifida occulta and bilateral sacralization of the first lumbar vertebra or bilateral lumbarization of the first sacral vertebra are not considered to be disqualifying defects. The former must be small and there must be no neurologic involvement. Individuals with spina bifida occulta are generally asymptomatic and only 0.1% of those with sacralization complain of back pain. Usually those who are symptomatic have unilateral sacralization (ref. 6). Those individuals with unilateral sacralization or unilateral lumbarization are not considered to be suitable candidates for ASD. It is noted that the radiographic screening criteria outlined by Thomas for NAMRLD ASD (ref. 11) differs from the criteria presented above, specifically in that NAMRLD candidates with transitional vertebrae are excluded and those with Schmorl's nodes are not excluded from participation.

#### SUBJECT ATTRITION AND MORBIDITY

During the past three years, no panel member has had to discontinue participation due to a deficiency in the medical screening evaluation procedure. During this time frame, qualified subjects leaving the panel either voluntarily withdrew for personal reasons, left military service, or changed permanent duty stations. However, 14 of the 49 members departing were disqualified from further participation for a variety of reasons (Table 5) by the Impact Panel Physician. Four subjects reported post-impact back pain which exceeded their expectations. Termination spine x-rays were not revealing and symptoms were attributed to mild/moderate paravertebral muscle strains. Another subject had onset of back pain following unrelated strenuous physical activity. He was eventually diagnosed by the neurosurgical consultant as having an intervertebral disc herniation which, by history, was believed to be unrelated to his participation as a panel member. This subject was eliminated from further participation. Other subjects were eliminated after discovery of hypertension, inguinal hernia, and pre-existent benign hematuria. The history of hematuria was not noted during the initial medical evaluation. More unusual circumstances led to the disqualification of other subjects: one had recurrent nightmares on evenings prior to scheduled impacts, another experienced recurrent episodes of vaso-vagal syncope several times during the pretest countdown, and a third demonstrated a clearly anomalous ("rag-doll") response to impact. Another subject was eliminated due to lack of participation.

<u>Reason for Leaving Panel</u>	<u>Number of Subjects</u>
Permanent Change of Duty Station	21
Left Military Service	7
Voluntarily Withdrew	7
Disqualified by Panel Physician	14
Back Pain	(4)
Herniated L4-L5 Disc (unrelated)	(1)
Hypertension	(1)
Inguinal Hernia	(1)
Benign Hematuria (pre-existent)	(1)
Nightmares	(1)
Vaso-vagal Syncope	(1)
Anomalous Response to Impact	(1)
Lack of Participation	(1)
Abdominal Pain (submarining)	(1)
Ligamentous Knee Injury (related)	(1)
Total	49

Table 5. Reasons for Members Leaving Impact Panel (1 Jan 77 - 31 Dec 79)

Subject morbidity from 1 Jan 77 to 31 Dec 79 has been limited, for the most part, to anticipated minor abrasions, contusions, and paravertebral muscle strains. However, due to harness lap belt pressure, one subject experienced a superficial lateral femoral cutaneous nerve palsy and another, presumably due to upper extremity venous congestion as a result of shoulder harness pretension, experienced a mild paresthesia in the ulnar distribution. During a -G<sub>x</sub> impact, a third subject "submerged" under the lap belt and, as a result, experienced significant abdominal pain post-impact. He required hospitalization and a liver-spleen scan to rule out splenic rupture. Surgical exploration was not required, but the subject was eliminated from further participation. The most serious adverse effect occurred during an 8G lateral or sideward impact in which the subject incurred an anterior cruciate ligament injury of the right knee requiring surgical correction. Factors contributing to this injury included the subject's extraordinary anthropometry and bracing mode (ref. 5).

# APPLICABILITY OF SCREENING TECHNIQUES TO UPT CANDIDATE POPULATION

Fifty-three percent (53%) of all ASD applicants processed between 1 Jan 77 and 31 Dec 79 were found not to be suitable candidates, as summarized in Table 6. The majority of those disqualified were on the basis of the medical evaluation and the majority of that subgroup were eliminated on the basis of radiographic findings. This high rate of positive radiographic findings is particularly startling in view of the fact that all candidates medically evaluated were "pre-screened" by virtue of having (1) satisfactorily completed an enlistment or commissioning physical and (2) provided a negative history of neck or back trauma to the Panel Physician during the screening interview.

<u>Reason for Disqualification</u>	<u>Percent of Total Applicant Pool</u>
Physician Screening	6%
Voluntary Withdrawal	14%
Medical Evaluation	33%
Radiographic Findings	(31%)
Other	(2)
Total Disqualified	53%

Table 6. Reasons for Candidate Disqualification and Percent of Applicant Pool Eliminated for Each Reason (1 Jan 77 - 31 Dec 79)

In order to assess the applicability of these techniques to the screening of aircrewmembers, the comparability of candidate populations for Undergraduate Pilot Training (UPT), e.g., and ASD must be established. There are several reasons for asserting that these two groups are comparable. First, both groups are essentially subsets of the active duty Air Force population, though many UPT candidates are technically derived from the cadet ranks of ROTC and OTS. Second, the appeal for adventure, to some extent, attracts the same type of individual to both volunteer groups. Finally, some Acceleration Stress Panel members have completed UPT and are on active flying status and others are accepted into UPT during their tenure as panel members. However, some individuals who do not qualify as panel members meet the physical standards for UPT and others who do qualify as panel members do not meet the standards for UPT. This circumstance may be explained by examining UPT candidate disqualification statistics.

Data provided by the Physical Standards Office of Air Training Command (ATC/SGPS) at Randolph Air Force Base indicates that approximately 6% of the more than 7400 candidates for undergraduate pilot or navigator training in 1979 were disqualified for medical reasons. The specific reasons for elimination of UPT candidates for 1979 are summarized in Table 7. Of those eliminated, a relatively high percentage was on the basis of visual defects. Since the only x-ray required during UPT candidate screening is a chest x-ray, very few candidates are eliminated on the basis of radiographic findings. Thus, the stringent UPT visual acuity standard and the absence of a UPT spinal x-ray requirement potentially permits UPT qualification of an individual who has been eliminated from consideration for ASD. On the other hand, the stringent AFAMRL spinal radiographic screening criteria and the lenient AFAMRL visual acuity requirement (up to 20/200 uncorrected) potentially permits qualification for ASD of an individual who has been disqualified for UPT.

<u>Defect Causing Disqualification</u>	<u>Percent of All UPT Applicants Eliminated</u>
Visual	43%
Allergic Rhinitis	16%
Height Requirement	12%
Auditory	7%
Orthopedic	4%
Gastrointestinal	3%
Circulatory	2%
Dermatologic	2%
Hypertension	2%
Neurologic	1%
Other	8%

Table 7. Distribution of Defects Causing UPT Candidate Disqualification (1979)

Since only 2% of the ASD candidates screened at AFAMRL from 1 Jan 77 to 31 Dec 79 were disqualified on a non-radiographic basis during the medical evaluation (Table 6), addition of PFT's, EEG, and exercise stress testing should not be expected to greatly increase attrition when added to the medical screening of a flying population. However, the benefit of the additional eliminations from such screening may be questionable, particularly in view of cost and yield. On the other hand, individuals with no history of a seizure disorder, e.g., may be found to have latent seizure activity on EEG. Elimination of such individuals prior to UPT is desirable. Two panel candidates were recently disqualified on the basis of this finding and, in fact, also were eliminated from UPT consideration for the same reason. The exercise stress test is somewhat indicative of conditioning and, as such, it may have a negative correlation with sustained G tolerance, since conditioned runners have relatively poor sustained G tolerance.

Conversely, radiographic screening of a flying population, utilizing the AFAMRL criteria, would be expected to greatly increase attrition, if the ASD applicant population is somewhat similar to the flying group. Less stringent radiographic criteria could be proposed which would moderate the expected attrition rate. If, however, the radiographic findings compiled above indicate some predisposition to spinal injury under impact loading, then we are left with the surprising conclusion that unscreened



flyers may have a relatively high potential for spinal injury in an ejection situation. In addition to the on-going efforts to improve escape systems, it may be beneficial to pre-screen candidates for operational flying in ejection seat-equipped aircraft using the three lateral spine films.

Medical screening for high stress flying must evaluate characteristics much more complex than impact tolerance. Sustained G tolerance, disorientation tolerance, heat stress tolerance, and capacity for high task loading are all relevant. There remains no simple medical screen to assess all of these functions. In fact, some are contradictory. The exercise stress test, for example, may indicate good conditioning and motivation which are helpful, but may also correlate with poor sustained G tolerance. It would appear that any adequate screen to select a subset of "super-flyers" for high stress flying would involve evaluation of actual flying performance in a realistic task, as on a centrifuge.

#### SUMMARY AND CONCLUSIONS

Recent AFAMRL experience with application of stringent medical screening techniques to a USAF active duty population has been presented. The following conclusions are provided.

1. Thirty-one percent of all applicants for Acceleration Stress Duty at AFAMRL from 1 Jan 77 to 31 Dec 79 were disqualified on the basis of positive radiographic findings.
2. The majority of these individuals could have been adequately radiographically screened by three lateral spine x-rays (cervical, thoracic, lumbosacral).
3. Since Schmorl's nodes, spondylolysis, and other similar radiographic findings are believed to be trauma-related, they may be indicative of a predisposition to spinal injury and are, therefore, considered to be disqualifying for Acceleration Stress Duty.
4. Subject performance improvement due to AFAMRL candidate screening is indeterminant, since unscreened controls were not exposed to impact accelerations.
5. Application of stringent spinal radiographic screening criteria to the UPT candidate population may result in an unacceptably high rate of UPT candidate disqualification.
6. Although we have historically designed high-performance aircraft escape systems to prevent spinal injury, we may not be adequately screening some aircrewmembers for radiographic abnormalities which may predispose them to injury during escape. Conceivably, aircrew candidates for training in high-performance aircraft may be screened with three lateral spine x-rays.
7. For high-speed, low-level flight with high task loading and air-combat maneuvering, additional screening procedures are conceivable, particularly if centrifuge testing with imposed task loading is considered.

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## DISCUSSION

DR J E WHINNERY (US)

1. What is the purpose of the single pregnancy test for the female ASD candidate?
2. Is the single pre-screen pregnancy test all that your Human Use Committee requires in addition to those requirements for males?
3. How do you assure a continual state of non-pregnancy in your long-term female ASD subjects?

AUTHOR

1. The purpose of the single pregnancy tests for female ASD candidates is to document a state of non-pregnancy at a single point in time during the medical evaluation.
2. We also require, as part of our initial medical screening, that all female ASD candidates undergo a pelvic examination by a gynecologist to rule out gynecologic contra-indications to participation. Such contra-indications would include, for example, large ovarian cysts or other pelvic masses.
3. Prior to their participation as human volunteer subjects, all females are counseled as to the inadvisability of becoming pregnant during their tenure as ASD subjects. Appropriate contraception counseling is provided as required. All female ASD subjects are instructed to inform the Impact Panel Physician immediately of menstrual irregularities.

DR F L JACKSON (US)

1. What measuring criteria do you use in rejecting candidates based on "excessive lordosis"?
2. Do you use supine radiographs for your measurements? If so, would not radiographs taken in the functional, seated position give a more accurate assessment of the relation between position and stress tolerance?

AUTHOR

1. We have established no firm criteria for disqualifying ASD applicants on the basis of excessive lordosis. Decisions to eliminate applicants on this basis are made in consultation with a radiologist and are individualised for each applicant. This criteria was established following an impact acceleration test in which a subject with an excessive lumbar lordosis incurred a coccygeal fracture.
2. Supine lateral lumbosacral radiographs are used to assess lumbar lordosis. We recognise that several other x-ray views would be helpful in candidate screening. However, we have agreed to limit the candidate screening x-rays to the fourteen films described above and recognise that we cannot optimally screen for all disqualifying radiographic defects.

DR C E SIMPSON (UK)

1. Can you confirm that 31% of all applicants were eliminated on the basis of disqualifying radiographic findings?
2. The criteria you quote are governed by Human User Requirements at AMRL. Can we assume that a similar screening procedure, employed for aircrew, would result in a considerably lower disqualification rate?

AUTHOR

1. We indeed eliminated 31% of all candidates on the basis of disqualifying radiographic defects of the vertebral column. Since 1 January 1980, we have eliminated well over 50% of the applicants on the basis of these defects. In this regard, it is important to note, for example, that recent articles have indicated the incidence of Schmorl's nodes may be as high as 76% in the general population (ref. 7).
2. However, due to the nature of the programme for which we are screening, our criteria are necessarily stringent. The number of individuals eliminated by spinal screening x-rays is a function of the criteria established for disqualification. Less stringent criteria may moderate the attrition rate. Such a more liberal approach would be reasonable when screening a flying population for duty in high performance aircraft. We do not propose which specific radiographic criteria be applied to screen a flying population on the basis of the data presented herein.

## THE MANAGEMENT OF UNFIT AIRCREW

BY

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SUMMARY

This paper examines the implications of unfitness in aircrew due to illness or injury. The author suggests a general philosophy of care and management directed towards an early and successful return to flying status. He highlights the role of the flight surgeon as an intermediary between the clinical specialist and the executive, who is responsible for co-ordinating the evidence required for a rational assessment of the fitness of the man as a whole. This needs to be based on a sensible assessment not only of the degree of risk to flight safety but also the ability of the man to do his job and have something in reserve. Risks of incapacity in the air must be quantified in a form which the executive can understand. Examples are given of an unusual case (chondro sarcoma) and of a common injury (fracture of spinal fractures). Conditions which currently pose problems of assessment are discussed - hypertension, peptic ulcer, manic depressive psychosis and alcoholism. Areas where further research and information are necessary are indicated. More emphasis on the effects on performance of drugs is required.

INTRODUCTION

I intend to address the subject of this paper from a personal point of view. This will be that of a flight surgeon and from the particular aspect of my recent experience over the past 6 years as Command Flight Surgeon, or as we in the Royal Air Force call it, Command Flight Medical Officer at Headquarters Strike Command. In this post I have had a unique opportunity to monitor the health and also a wide variety of illness and injury in a large population of trained military aircrew operating in many different aircraft, roles and tasks in a full spectrum of offensive military operations.

Aim

My purpose is to examine the implications of aircrew illness or unfitness and the problems which arise in assessing fitness to return to successful flying. I propose to show that there is a need for close co-operation between flight surgeons and specialist clinicians, and in many cases the executive, in determining when and how aircrew can return to flying status. I also intend to submit that we may need to rethink some of our traditional attitudes in the light of many of the radical changes in medical thinking and practice which are taking place. We must assess risk levels which while giving an adequate margin of safety do not unfairly and unnecessarily penalize aircrew. I will venture to suggest that perhaps more emphasis is required on the man's performance than on the possible risks of incapacity.

CONSEQUENCES OF UNFITNESS

First of all, what are the implications of aircrew unfitness for the executive? Management is aware that trained aircrew represent a considerable financial investment. Our Secretary of State for Defence recently quoted a figure of approximately £ 5 million as the cost of training a fast jet pilot to the point where he joins his first operational squadron. In the event of illness or injury that is a lot of money lying idle. There is therefore much to be gained in amortizing these costs if such aircrew can be returned to flying status as soon as possible. It therefore follows that aircrew need priority treatment, and that waiting lists for treatment and investigation are unacceptable. Military management therefore do well to remember that this is the main justification for a separate dedicated military airforce medical services including hospital facilities. There are, as all know, do not come cheaply and must be seen to be giving good value and the service management expect operators are keen for their aircrew to return as soon as possible for obvious reasons - it eases the load on the rest of the squadron aircrew and improves their capability. On the other hand the advantages of an early return to flying status need to be balanced against risks to flight safety. This affects both management and operators as the executive are particularly sensitive to public concern, press reaction and financial liabilities and losses should an aircraft accident result. As many therefore agree with the executive acceptable risk levels. To do this we need to understand the operational stresses and dynamics to which aircrew may be subjected in various aircraft and different roles. We need advice on the consequences of aircrew incapacity in the current competent crew regularly trained to detect and handle emergencies. Single pilot aircraft pose a higher degree of risk than two pilot aircraft. In some cases the reliability of aircraft and the dependability and degree of use of autopilots and similar systems, and the individual crew's experience and level of training of the crew may influence the assessment. The majority of human factor accidents are associated with loss of control of the aircraft. Removal of a trained airman all too often means his replacement

by one with less experience and ability. What are the implications for the man himself? He sees his return to flying status as the confirmation of his recovery from the insult of illness or injury and proof of his return to health. It represents a return to his chosen career and way of life. It means the revival of his career prospects and financial security from the point of view of safeguarding his flying pay which in many cases is a significant proportion of his total remuneration. He is therefore very strongly motivated towards a return to flying and will therefore tend to minimise symptoms and disabilities. This may induce the medical authorities to return him too early to flying stresses with a resulting disappointing breakdown. We must also remember that stamina, morale and confidence may have been sapped by his illness or injury - particularly when associated with a flying accident.

What about the medical authorities? We expect our clinicians to be competent, caring and conscientious. There is a tendency, however, for them to be enthusiastic, perhaps even sometimes over enthusiastic over new methods of treatment and new drugs. They may therefore be carried along with the patients wish to resume flying, particularly if they are unaware of the actual operational stresses and skills required. There must be a rational assessment as to whether the patient is fully recovered, physically, mentally and psychologically. If there is any residual disability, sensory or motor or both it must be determined if he can still do his job and has he any reserve left. If he has a condition where illness or incapacity could occur in the air, the risk to flight safety must be assessed. The clinician often lacks knowledge of what the operational task requires and what the consequences of aircrew incapacitation might be. The Flight Surgeon is best placed to give this advice both from his knowledge of the aircraft, the role, the task and the training of the crew and his own opinion of the man's ability and personal qualities. He is also well placed to obtain the advice of the executive on their assessment of the man as an operator and his ability to cope with the task and emergency situations with a disability. The Flight Surgeon is the broker (in insurance terms) between the clinician and line management. Where anxiety may be a problem the Flight Surgeon will need to interview the wife to gain information on attitudes, on behaviour in the domestic scene, changes in sleeping and eating, drinking and smoking habits which is relevant to the assessment of the patients recovery or a decision that he be withdrawn from flying status.

#### REHABILITATION

At this point I would like to stress the importance of an active programme of convalescence and rehabilitation. We in the Royal Air Force have developed in WW II rehabilitation units where, following hospitalisation servicemen can receive a graduated programme of physical training and occupational therapy. This is intense but carefully regulated to the man's capabilities and stage of recovery. It concentrates on improving physical and mental fitness, power and co-ordination in a stimulating and competitive atmosphere. There is no doubt that this approach has been successful in returning individuals to a flying career and even where return is not possible, has considerably alleviated the bitterness of failure.

#### ASSESSMENT OF FITNESS FOR RETURN TO FLYING

The critical time comes when return to flying status has to be considered. As I have explained it is essential to obtain a total picture of the man and his problem. Only with this is it possible to recommend a suitable method of return to flying status which is in the best interest of the man and the Service.

Often the issues are relatively clear cut or appear to be. To give an example of actual cases I will first quote that of a young air electronics operator who unfortunately developed a chondro sarcoma of the R heel towards the end of his training. He underwent a below knee amputation. He started physiotherapy early on in the healing of the stump and made rapid strides (literally and metaphorically) once his prosthesis was fitted. The problem then was whether to allow him to complete his aircrew training.

The task of an AEOP in the maritime role is sedentary in the 'dry' (radio/radar) duties and involves some standing in 'wet' or sonic duties. This was obviously within his capacity. It was possible to quote other examples of amputees AEOPs in the maritime force and other aircraft who had given useful and successful service without undue constraints or limitations. In the Nimrod problems of ejection or bailing out do not arise. In other aircraft where the patient could be employed as an AEOP the possession of an artificial leg could conceivably hinder ability to bale out and affect parachute landing. On balance, however, the risk was considered acceptable to the Service if acceptable to the individual. There remained the ultimate prognosis and its implications. From the flight safety point of view illness or incapacity of the AEOP would represent no hazard. However, if further problems, ie secondary lesions did occur he would become permanently unfit for further aircrew duty (to say the least) and there would be a financial loss as far as his training costs. On the other hand his executive reports were fine and he had already showed excellent motivation and aptitude. Clinical opinion was that recurrence risk was now low and he was therefore given the benefit of any doubt and returned to complete AEOP training and is now operational. You will see that in the management of such cases the flight surgeon represents the essential link between the executive and the clinician and can advise an acceptable solution. Some conditions are more common and often a routine scheme of management has evolved. Let us take ejection injuries to the spine. These commonly take the form of stable, uncomplicated wedge fractures of vertebral bodies - usually in the dorsal region. Often they, if minor, are relatively painless and sometimes

have been missed on initial clinical examination. Indeed the Israeli Air Force in the Yom Kippur War had some pilots who after ejection went back into battle almost immediately but who were subsequently found to have such lesions. It is important that these are diagnosed and treated - even if discomfort is minimal - to fly with such an unhealed fracture is to run the risk of further damage and even neurological complication if high g forces are applied in combat training or God forbid a second ejection. Thus we require all our aircrew after ejection to undergo early referral for orthopaedic opinion and careful radiological examination. If compression fractures are present the patient is admitted to hospital for a minimum of 3 weeks. Once pain-free, graduated physiotherapy is commenced - particularly spinal extension exercises. If at the end of this time the patient is pain-free, has good muscle power and has regained full spinal extension he is allowed to return to non-flying duties. Three months after injury if at review he is still pain-free and has full ranges of spinal movement he is allowed to return to full flying duties, including the risk of further ejection. The long term prognosis is good and subsequent backache infrequent.

#### PROBLEM AREAS

My concern, and the reason I suspect for this meeting, is that others share it, is that even with such a system as I have described, and even with supposedly clear-cut conditions such as ejection spinal injury there are many problem areas which exist when deciding when and how to return aircrew to flying duty.

These may be summarised as follows:

- (a) Where the degree of injury or disability is difficult to assess.
- (b) Where the risks of returning to flying duty are difficult to define.
- (c) Where a symptom-free patient has an unsuspected or dormant clinical condition.
- (d) Where new treatments and advances in medicine or surgery are changing management.
- (e) Where prognosis is difficult or unknown.
- (f) Where treatment by medication has to be life long.
- (g) When indications to start such treatment are not clearly defined.
- (h) When illness, eg low back pain results from ergonomics and poor design.
- (i) When deep rooted anxieties remain.

#### WHERE DEGREE OF INJURY OR DISABILITY IS DIFFICULT TO ASSESS

Let us go back to the problem of ejection spinal injury. Radiologists and orthopaedic surgeons may sometimes have difficulty in confirming a minor ejection fracture. They have proposed - and indeed some Air Forces take spinal X-Rays of aircrew prior to flying training - these can then be compared with those taken after ejection. It also may show-up spinal abnormalities, eg a vertebral body haemangioma which might collapse under high g and/or ejection, congenital lesions, eg spondylolisthesis/spina bifida which might go unnoticed until later on after expensive training.

We in the Royal Air Force have not carried out such a prospective screening examination which would be costly, and would increase the rejection rate still higher. It is interesting that our ejection injury rate is no higher than in those air forces who do such screening. Furthermore the radiation dose is relatively high. To introduce a screening programme retrospectively would produce problems of making fit aircrew unfit and generate in aircrew suspicion and antagonism towards the medical branch. Thus we are left with the problem of difficulty in assessing presence of minor ejection damage and tend to err on the side of safety.

New treatments and recent advances in medicine and surgery also pose problems. Prognosis may be difficult or unknown - where treatment may have to be lifelong and we cannot predict long term effects in some cases, the side effects may not be recognised for a while. If treatment means limitation of flying - when should we start, particularly if some decrement in performance is possible? Do we emphasise the short or long term implications of treating or not treating? I would like to discuss three conditions - hypertension, peptic ulcer and manic depressive psychosis where new advances and treatment have revolutionised management.

#### HYPERTENSION

Thirty years ago the only treatment which could be offered for essential hypertension was sympathectomy. Then in the 1950s the hexa-methoniums introduced what is today a range of effective drugs which can provide protection against death and disability from heart failure, renal damage, and stroke associated with moderate and severe hypertension. On the other hand use of these effective drugs to control hypertension has not cut deaths from myocardial infarction which the Framingham Studies showed

to correspond with hypertension. (1) The clinical dilemma when faced with aircrew who show mild hypertension and who feel fit and symptom-free is multi-faceted. There is considerable divergence of opinion as to when treatment should begin. A BP of 140/90 is commonly taken as the border-line for aircrew - obviously a single record is inadequate and clinicians tend to assess a case on the basis of a large number of casual records. These may be subject to effects of apprehension and often so-called resting levels are called for. Yet what we really need as a basis of evaluation is a continuous daily record - unfortunately no satisfactory non-invasive method of recording has been devised. In experiments with invasive methods the blood pressure is shown to vary considerably throughout the day, with circadian cycles and marked responses to dynamic exercise and smoking, but surprisingly little effect when exposed to the stress of car driving. (2) We have yet to obtain such records of pilots carrying out operational missions, high g manoeuvres, air combat, air-to-air refuelling, low-level tactical flying and instrument flying in difficult and dangerous situations.

Accidents caused by incapacity in the air are surprisingly few in number compared with those associated with human error. Lack of skill, experience and judgement are usually the cause. To my mind, research on side effects of drugs has been far too slanted towards tolerance and response to stress than on the possible decrement to clear thinking and psychomotor skills.

We have also recently seen that treatment of mild hypertension is beneficial. (3) At present aircrew with hypertension can only continue unrestricted flying if they can be controlled by thiazides, rauwolfia or spironolactone - and readings of 170/100 are considered for loss of licence in civil flying. These drugs however all can cause central side effects which could degrade performance - but there is little work on effects of psychomotor performance and less evidence. A lot has been done on response to stress, but not how well the individual can do his job. Clinicians are keen to use the newer more powerful drugs and achieve better control and thus prolong an active flying career. However, these drugs, too, have side effects - some may be mild and cause some marginal mental and physical slowing down - is this acceptable? Again we have little relevant information: Broadhurst has reported definite decrements in psychomotor performance lasting up to 3 weeks using small doses of propranolol. (4) In many cases the patient makes the decision and simply does not comply with the regime. Ideally any treatment must be symptom-free and once a day medication. It should be shown not to degrade performance by sedation as well as not reducing g tolerance or resistance to orthostatic stress and should produce no dangerous long term side effects. We have heard the propranolol story and the mucocutaneous syndrome, reports on peripheral arterial disease and sclerosing peritonitis. Therefore it is with considerable interest that I look forward to the contributions on this subject tomorrow.

#### PEPTIC ULCER

There has been an unexplained fall in the incidence of peptic ulceration in the past 20 years both in the US and UK and this has been reflected in fewer aircrew presenting with a condition which used to be treated by a long period of grounding (12-18 months) and often by surgery - usually vagotomy and pyloroplasty. However introduction of first deglycyrrhizinised liquorice and later Cimetidine has revolutionised treatment in civil practice and further reduced candidates for surgery. Development of sophisticated fibrescopes and associated techniques has permitted more accurate control and follow-up. Nevertheless it is becoming apparent:

- (a) That cimetidine treatment may need to be lifelong and expensive.
- (b) That occasionally side effects occur - bradycardia, thrombocytopenia, pustular psoriasis and even coma have been described.

What should be our policy for aircrew, what are the effects on psychomotor skills and is the possibility of side effects an acceptable risk to flight safety? Do they require restricted employment with a regular life? Should they undergo functional assessment by simulator instructors or QFIs or perhaps a computer analysis of a flight recording of say a standard IF task.

#### MANIC DEPRESSIVE PSYCHOSIS

Mild degrees of this illness are common in civil life and individuals can without treatment do good work in their hypomanic phases and retire when depressed. Aircrew cannot, however, regulate their own timetable. A treatment which gave early promise of permitting aircrew with manic depressive psychosis being able to return to flying was lithium. However, our experience has been disappointing - one helicopter crewman attempted suicide by taking all his lithium supply at once and required renal dialysis. When grounded his second suicide attempt was successful. Although lithium gives long term freedom from attacks and relapses in civil practice we don't know how well they really are on medication. Personality testing still gives a depressive response, treatment has to be indefinite and requires a high degree of patient cooperation and compliance in personalities which may be far from good.

#### SARCOIDOSIS

An example of a condition where the risk of return to flying duty are currently difficult to assess is Sarcoidosis. It is also a condition which frequently may be

dormant, discovered by chance and is often symptom-free. As you know the aetiology is obscure and many theories have been put forward. Until 1978 the Royal Air Force has regarded Sarcoidosis as a condition which ran a benign and self-limiting course, the so-called sub-acute form. The presentation was usually in the form of a transient erythema nodosum and a hilar adenopathy shown on chest X-ray. This lasted a few months and resolved spontaneously without treatment. Only rarely was there an acute presentation with diffuse pulmonary infiltration, ocular and bony lesions and involvement of the CNS. Heart, liver and splenic involvement and persistent skin lesions might occur. Treatment involved all branches of medicine but was symptomatic and usually required steroids. Such cases formed a less common group and invariably after the acute onset drifted into a chronic state. This I believe is more chronic in the USA than Europe.

Our clinical management of sarcoid in aircrew was to ground those with the sub-acute form until activity had ceased. This was assessed on the basis of X-ray appearances, absence of symptoms and origins usually a period of 6 months was sufficient. They then returned to flying with little restriction apart from annual chest X-rays and examination for a few years. Cardiac assessment was rarely carried out unless specific symptoms occurred.

However in 1978 a Vulcan aircraft crashed in the USA and the investigation highlighted a difference between the RAF and USAF policy on Sarcoidosis, although there was no serious indication that the disease caused the accident. The pilot alone tried to escape - ejecting too low and too late and he received fatal injuries.

Autopsy revealed that the pilot who was under observation for Sarcoidosis found 6/12 before (discovered by routine chest X-ray to have hilar adenopathy) had definite cardiac sarcoid. It was then recalled that three years before an RAF F4 Phantom had crashed after going out of control in a low flying area. Although the navigator ejected safely, the pilot made no attempt to do so and was killed. Autopsy showed typical sarcoid lesions in the lungs which had been unsuspected (he was overdue chest X-ray and annual medical!) The heart was missed. Although the Board of Inquiry suggested a technical fault as the cause of the crash this was by no means conclusive and pilot incapacity as an explanation could not be excluded.

Following the 1978 accident we also became aware of increased USAF and US Army concern at the aeromedical risks of cardiac sarcoidosis and of similar concern by UK civilian specialists. It was therefore decided to mount prospective and retrospective surveys of Sarcoidosis in RAF aircrew. The prospective study has been to X-ray all aircrew and identify any unsuspected cases. Known cases on the register were re-examined from the cardiac point of view using a non-invasive protocol based on USAF SAH recommendations. This includes gallium 67, thallium and technetium scans to detect any active lesions in chest or heart.

This retrospective survey has involved temporary grounding of some 17 known cases, 13 from Strike Command. Satisfactory cardiac screening was followed by medical boarding. In most cases a return to flying as or with qualified co-pilot or as unfit solo navigator permitted useful employment, but in one or two cases - eg fast-jet and helicopter pilots this presented problems.

The final results of this survey have yet to be published but we would welcome any comments on the experience of other nations of sarcoid in aircrew. We believe more research is required to determine if Sarcoidosis is commoner in aircrew than in an equivalent ground personnel population and if so, why? Is the disease encouraged by high oxygen partial pressures? The management of future cases will obviously require cardiac assessment and very careful determination of any residual cardiac activity before a return to flying status. Some indeed argue that sarcoid is a bar to flying, however, I feel that a helicopter pilot who continued to fly for 20 years after his asymptomatic condition was diagnosed has perhaps proved a point and retain an open mind. We must determine if the flight safety risk is acceptable but we can only do this if we know what the level of risk is and what is acceptable to the executive. I would have liked to have talked about the problems of postural backache and phobic anxiety, but time does not permit. Suffice to say that in both these conditions the role of the Flight Surgeon in prevention, diagnosis and management is paramount.

#### CONCLUSIONS

Gentlemen,

I hope I have shown the need for a medical intermediary between the specialist clinician and the executive, and that for aviators that doctor must understand the needs of both, but primarily he is there to consider the man himself from all aspects when it comes to assessing his return to flying status after illness or injury. I hope I have indicated where I think we need to develop new standards, new methods of management and to direct our research into side effects of drugs more towards their effects on the individual's capability to perform his job, rather than possible incapacity. This is an area where there may be room for more standardisation of practice among NATO Nations based on a sound statistical basis and less on independent clinical whim.

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### DISCUSSION

DR F L JACKSON (US)

Your paper highlights many of the problems experienced by US Navy Flight Surgeons. A survey of Flight Surgeons had indicated that a minimum period of 12 months was indicated before aircrew who had ejected return to ejection seat flying. What criteria have been used to allow a return to flying after 3 months?

AUTHOR

We believe the fracture is healed.

DR B F HEARON (US)

In regard to your comments on ejection injuries, I concur that it is often difficult to establish a diagnosis of a vertebral fracture post-ejection. I have recently completed a review of the F/FB-111 accident ejection data and have been concerned that some of these injuries were retrospectively diagnosed on the basis of spinal x-rays taken years following the ejection. In view of the high incidence of spinal radiographic defects which I have presented, I do not believe that it is valid to attribute non-specific spinal radiographic findings to a specific remote trauma, such as an ejection. A radiologist colleague has recently recommended that vertebral fractures incurred during ejection be diagnosed with the aid of a bone scan taken 4 to 7 days post-ejection.

However, I do not agree with your statements regarding spinal screening x-rays for aircrew members. I believe that such spinal screening x-rays, particularly lateral spine films, are entirely appropriate in the "at-risk" flying population. It is very important, for example, to eliminate as a potential flyer an individual with Scheurmann's disease, which involves end-plate defects at multiple vertebral levels. Such an individual was recently identified by our own screening procedure and he was eliminated from consideration for Impact Acceleration Stress Duty.

AUTHOR

The debate may well be whether the cost of screening is justified by the return you get from it.



A SOLID-STATE DARK ADAPTOMETER  
THE LAIR DARK ADAPTOMETER

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SUMMARY

The eye's ability to adjust from a very bright light to a very dim light environment is known as dark adaptation. The lack of this ability may be a congenital deficit or the ability may be severely altered by a disease (e.g., retinitis pigmentosa). Active duty soldiers may be not aware of their inability to "see" at night. These soldiers may be in command of companies or platoons in night maneuvers. Unintentionally, these persons may jeopardize the lives of other military personnel and allies, and destroy equipment. The magnitude of this dark adaptation problem in the military, specifically with the active duty fighting soldier, has not been fully documented. Presently, dark adaptometers are complex optical devices. They can not be easily relocated and are not accessible for screening military personnel in the field. For this reason, a new type of dark adaptometer has been developed at Letterman Army Institute of Research (LAIR) which is a piece of apparatus considerably less complicated than other dark adaptometers. Interface with a low-cost microcomputer system allows clinical flexibility for routine military screening and research flexibility for investigators studying the role of dark adaptation in military tasks. The data presented validate the use of this device for such applications.

INTRODUCTION

Many of the current field exercises conducted within the Army involve extensive night maneuvers. Such exercises place large numbers of personnel and millions of dollars of sophisticated weaponry into a scenario. No accurate measurements have been made assessing the ability of these troops to adapt to low-level light or perform in night operations.

Recommendations have been made for the development and wide-spread use of a device to screen recruits and active duty military personnel for dark adaptation. It is estimated that perhaps as many as 15 percent of the "normal" population has some difficulty in altering light sensitivity in darkness. If the military has within its ranks a similar percentage of adaptation problems, there may be a platoon sergeant, company commander, tank commander, or others in a night exercise with minimum ability to adapt to the low-level light environment. Unintentionally, this individual may jeopardize the lives of other military and destroy friendly lives and equipment because either the individual cannot adapt or has not realized that adaptation is a problem.

The subjective phenomenon of dark adaptation is familiar to us as the initial inability to "see" when entering a dark room from a bright-light environment. The longer we stay in the darkness the better we can see. The sensitivity of the fully dark-adapted human eye is unsurpassed by even the most sensitive physical detection systems. The functional relationship that describes this increase in sensitivity with reduction in ambient light levels is known as dark adaptation. Our purpose in this paper is to show how the military can improve the measurement of dark adaptation in its personnel.

The quantitative measurement of this process has traditionally been a complex problem. The technique involves various light sources, filters, optics, and graphic data reduction. A two-step procedure is always involved. The visual system must be brought to a standard level of light adaptation and then, subsequently, the temporal course of visual threshold in the dark-adapting eye can then be measured over a subsequent 20 to 30 minutes of darkness. The typical function measured in this manner for a large retinal area with an unfiltered white light test source passes through an initial plateau at about five minutes ("rod-cone break") before achieving a final plateau 20 to 30 minutes after the termination of light adaptation. The initial portion of dark adaptation measured in this manner is attributed to the dominance of cone function over rod function during the early minutes of dark adaptation. (The cone system is the human photoreceptor system that mediates color vision and visual acuity. The human rod photoreceptor system mediates absolute visual sensitivity.) The final dark-adapted threshold, occurring 20 to 30 minutes after light adaptation, reflects the dominance of rod vision and the ability of the rods to detect minimal light levels.

While conventional clinical dark adaptometry has traditionally employed a white light test stimulus and relatively intense light adaptation exposure levels, other approaches to the separation of rod and cone dark adaptation processes are possible. If dark adaptation functions are measured with spectral (monochromatic) rather than white light test sources, functions varying in steepness and rate of adaptation are obtained as a function of spectral (monochromatic) location (1,2). Functions measured with red light are generally more shallow and rapid in adaptation. They appear much like functions measured for central retinal regions that are dominated by cone photoreceptors (3). Functions measured with green or blue-green lights are steeper and require more time for full adaptation. Such functions are more of a composite of both rod and cone processes. By appropriate selection of test light wavelengths and retinal location, such functions can be made to reflect specific local retinal receptor processes.

Until recently, the measurement of spectral dark adaptation functions of any kind has been even more complex than conventional measurement of dark adaptation with white light sources. The development of light emitting diodes (LED) that emit selectively in the long (red) and in the intermediate (green) spectral regions has changed this situation. In this paper, we will introduce a new solid-state dark adaptometer recently developed at the Letterman Army Institute of Research (LAIR) that uses red and green

LED sources to separate rod and cone function in a rapid and a simple automated technique for spectral dark adaptometry (4).

#### THE LAIR DARK ADAPTOMETER

A composite illustration of the LAIR dark adaptometer--its principle of operation, pulse modulation; and its product, a sample individual dark adaptation function--is presented in Figure 1. A 36-inch hemisphere, fitted with a chin support and headrest, can be indirectly illuminated to provide a constant uniform light adaptation source of 110 candela/m<sup>2</sup>.

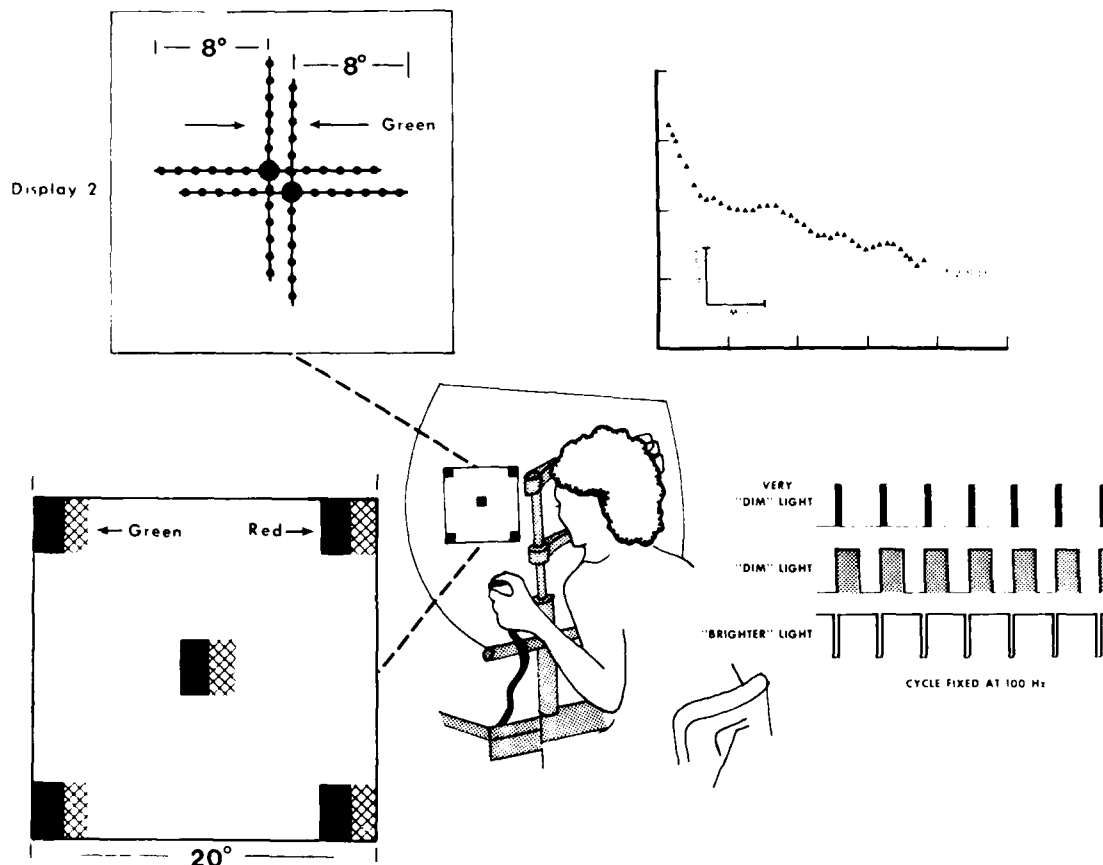


FIGURE 1. A schematic illustration of the LAIR dark adaptometer with interchangeable display modules. In the upper right, a sample dark adaptation function from one individual as drawn under computer software control by the X-Y plotter is shown. The upper and lower solid lines represent two standard deviations about the mean function. The duty cycle or pulse width modulation for a dim light (late dark adaptation) as compared to that of a bright light (early dark adaptation) is shown in the lower right insert. Threshold pulse width decreases as dark adaptation increases.

Red and green LED sources are mounted inside the hemisphere and are used in either of two display modes. In Display 1, five blocks of LED red and green sources are mounted on a board. At their widest separations, they subtend an angle of 20 degrees at the retina (Figure 1). This diode array was specifically designed to test within a large area of the retina without the use of any specific fixation point. The subject is simply instructed to respond when any test light is just visible. In Display 2, specific fixation to a central fixation diode is required. Any retinal area over an eight-degree region of the retina can be focalized by this arrangement and local spectral dark adaptation of this retinal region measured. If the proximal ring of diodes is chosen, the dark adaptation measurement will reflect adaptation primarily in the central retina (foveomacular dark adaptation). If the outermost ring of diodes is chosen at eight degrees from fixation, then a peripheral retinal dark adaptation function will be obtained. The display contains two complete "crosses," one comprised of red and the other comprised of green LED sources. Each display is a separate modular unit. Changing modules from one to the other involves plugging in the appropriate diode display board into the same control socket.

Visual threshold measurement in this apparatus was made by a pulse modulation procedure where pulse width varied from one to 10,000 usec at a pulse repetition frequency of 100 Hz, a value above fusion flicker threshold. In this pulse domain, average quantal flux rather than peak power determines threshold level. Thus, for a constant peak output power of the LED, the total average quantal flux

The use of the 8253 timers minimizes computer participation in timing and counting operations and thereby frees the CPU for the performance of other tasks. Each 8253 contains three independent 16-bit down-counters which may be operated at clock frequencies up to 2 MHz. Each counter is provided with a clock input, an output, and a gate input which can be used to reset, stop, or start the counter. The

counters can be programmed to operate in several different modes. Once programmed, the counters perform their assigned tasks without further supervision by the computer.

The 8255A PPI is a general purpose 24 line input/output device. The PPI input/output pins are organized as three eight-bit ports (A, B, and C), the functions of which are under the control of the microprocessor. The LED adaptometer uses port A of the 8255 as a latched output device. In this mode, a control word output to the port will activate selected bits which can then be used to control the operation of other devices on the interface board. The bit pattern will be retained until the next data byte is sent to the PPI. The outputs are used to synchronize timing operations, to control an adaptation light, and for selection of stimulus display elements. The numerous ports of the PPI permit the control of complex stimulus displays. Port C of the PPI is programmed for input operation and is used to monitor the status of the response button.

The 8253 designated IC2 generates the LED duty cycles and flash rates. The 100 Hz, controlled duration pulse train from IC2, OUT 2 is connected to the inputs of NAND gates IC4A and IC4B. The other inputs to these gates are connected to the PPI output control lines labeled "red" and "green". Data sent by the computer to port A of the PPI can selectively activate these control lines. When either of these lines is activated, the corresponding NAND gate will be enabled and the LED duty cycle pulse train will be transmitted to the corresponding stimulus display. The 8253 labeled IC3 is used as an elapsed time counter. This device is used for timing the durations of the light and dark adaptation periods, delaying changes in duty cycles, and as a source of elapsed time data for use during plotting.

The PPI controls an incandescent adaptation light via the output labeled "light." When this output is high, a solid-state relay switches a tungsten filament light "on." This light is used to light adapt the subject under controlled conditions prior to the start of the dark adaptation test. The "response" connection to port C of the PPI is used to monitor the status of the response button. The button is debounced by NAND gates IC4C and IC4D with the output of the former being connected to one of the PPI inputs. When the push button is released, the input will be high. This condition can be recognized by the computer by reading a byte of data from port C and then masking (ANDing) the result to isolate and test the bit corresponding to the "response" input.

**Software.** An abbreviated version of a BASIC program which uses the method of limits to derive separate adaptation functions for the red and green LED test stimuli is listed in the Appendix. This program stores the 8253 count values which control the LED duty cycles in array L( ). The array L( ) contains 81 count values covering a four-log-unit range in increments of 0.05 log units. The shortest duty cycle is approximately 1  $\mu$ s (two counts for the 2.048 MHz clock input) and the longest is 10000  $\mu$ s (20480 counts). The table entries are computed in lines 1330-1370. The expression in line 1340 derives the log duty cycle values and converts them to integer multiples of the system clock frequency. The integer expression in line 1340 limits the precision with which the constant log interval can be approximated. The values computed in line 1350 and stored in the array P( ) are the equivalent log values (times 100) of the actual integer counts stored in L( ). The pre-multiplication of the data stored in P( ) scales the numbers for use during plotting.

Initialization of the programmable integrated circuits is accomplished by the instructions in lines 1400-1510. The program begins with output of an operating mode instruction which defines the task to be performed by one of the counters or ports. The mode control word contains the operating instructions and the coded address of one of the functional units within the device. Each counter or port is programmed separately. The 8253 counters also require initial count values. These are written to the appropriate address as one or two bytes of data. The 8255A is instructed to perform simple input/output operations in line 1410. Subsequently, data output to port A will be held by the 8255A until reprogrammed. Similarly, by reading data from port C, the current status of the input pins can be examined. Data appearing at the input pins of IC1 are not latched when using this mode of operation.

The software implementation of the method of limits derivation of the dark adaptation functions is found in lines 1670-1860. Each stimulus presentation starts with an ascending series. The starting duty cycle value is set 0.75 log units below the last threshold (arbitrarily set to 2.5 log units on the first presentation), the appropriate LED display is switched on, and the current elapsed time is recorded. The program then enters a loop (lines 1720, 1730) during which the status of the response button and the current time values are evaluated. If no response occurs within 0.5 s, the duty cycle is increased to the next highest value and the procedure is repeated. If a response is made, the program stores the current log duty cycle value. The duty cycles are then incrementally decreased until the response button is released. The corresponding log duty cycle value is again recorded. The absolute threshold for the trial is the average of the log duty cycle recorded during the ascending and descending limbs of the series (line 1860).

After each threshold estimate is obtained, the LED display is switched off (line 1890) and the results are plotted (Figure 2) using the subroutine beginning with line 2150. The status of the elapsed time bit of IC1 port C is checked after each data point is plotted. If the programmed time interval has expired, an end-of-session message is written to the video terminal and all LEDs are switched "on" to alert the subject that the test has ended. If the test has not ended, the color of the stimulus display is changed and program execution resumes at line 1970.

The elapsed time counter is accessed by the subroutine beginning with line 2370. The instruction in line 2380 is used to latch the current count value in the 8253. This operation does not interfere with the count operation. Since this 8253 is programmed as a 16-bit binary counter, it is necessary to read the count register as two bytes of data. This is accomplished in line 2390 where the decimal value is reconstructed from the low and high data bytes and assigned to the variable SEC.

The software used in our laboratory allows the operator to change any of the dark adaptation test parameters through commands entered at the video terminal. Other software options include 1) exponential smoothing of the plotted adaptation functions, 2) detection of response errors, 3) use of a fixation point with automatically adjusted intensity, 4) selection of alternative psychophysical test methods, and

5) creation of data files on magnetic disk for subsequent statistical analyses. The unused output lines of the 8255A have been used to control more complex stimulus displays.

**Procedures.** For the data presented in this paper, the following protocol options were used. Light adaptation for five minutes at a hemispheric illumination level of 110 candelas/m<sup>2</sup> was given to each subject. Light adaptation was followed by 20 minutes of darkness, during which time threshold estimates were continuously made for both spectral light sources. The psychophysical method of limits was used to derive the adaptation functions for the red and green test stimuli. A trial began by setting the apparent intensity (duty cycle) below the last estimated threshold value. The apparent intensity was then incremented in equal log steps. Each level was present for a fixed time interval during which the subject either failed to detect the stimulus or reported detection by pressing the response button. Once the stimulus was detected, the intensity was decremented until the subject signaled by release of the button that it was no longer present. The absolute threshold for each trial was the average of the log values at which responses occurred during the ascending and descending series. Thresholds for both red and green LED sources were continuously tracked over the 20 minutes of darkness in this manner. When a fixation source was employed, the subject was carefully instructed not to depress the response button until the light other than the fixation source was detectable. The computer automatically signaled the end of the test by displaying all of the LED sources at level above detection threshold for the dark-adapted eye.

A total of 21 human volunteers (average age 25; 3 women and 18 men) were tested. One of these volunteers was a referred patient (man, age 23 years); one was a 50 year old male protanope.

## RESULTS

Dark adaptation functions measured for 19 human volunteers for both the red and green LED sources are shown in Figure 3. These data were obtained by using LED Display 1 where thresholds were measured without fixation within a nonspecified 20 degree retinal area. Average threshold values were calculated at 1.25 minute intervals over the 20 minute dark adaptation period for both the red and green LED sources. The inner horizontal bars about each threshold point represent  $\pm 1$  standard deviation, whereas the outer horizontal bars about each threshold point represent  $\pm 2$  standard deviations about each mean threshold point. The variability of the curves is approximately  $\pm 0.5$  log units over the entire 20 minute range of dark adaptation. The green LED function is slightly more variable at five minutes than at other times during the dark. (This variability may reflect individual differences in the rod/cone break of the dark adaptation function.)

The basic shapes of these functions are not similar. The dark adaptation function for the green LED covers nearly a two-log-unit range as compared to less than a log-unit range for the red LED function. Dark adaptation is more rapid for the red LED source than it is for the green LED source. (This also reflects the possible operation of more than one photoreceptor system measured with the green LED.)

Data from a single volunteer are presented for comparison with the normal data (Figure 3). On the green LED for this subject, data points fall more than three standard deviations above normal values throughout most of the dark adaptation period. While he was closer to the norm for red LED function, his data were still more than 0.5 log units higher than threshold throughout the dark adaptation period. This subject was diagnosed as an individual with peripheral retinal disease; he had complained of his lack of being able to see at night. His vision under daylight condition was within normal limits as measured on standard tests of spatial vision (6).

Dark adaptation functions measured (Display 2) at three eccentricities from fixation are presented for one representative normal human subject (Figure 4). From this figure, one can compare the measurements at one degree eccentricity between the normal human volunteer and a human protanope (a person who has difficulty in making color discriminations in the red region of the visible spectrum). At an eccentricity of eight degrees, the red and green LED sources yield dark adaptation functions similar to those shown in Figure 3. However, as eccentricity from fixation is made more central, dark adaptation for the green LED becomes more shallow and an overall increase in threshold occurs. While the slope of the function for the red LED changes little as threshold measurement becomes more central, an overall increase in visual threshold for the red LED occurs. Data from the human protanope relative to the normal human at one degree eccentricity are considerably higher in threshold for the red LED than for the green LED.

## DISCUSSION

In this paper, we have introduced a new dark adaptometer, the LAIR dark adaptometer, and data that validate its usage. Spectral dark adaptation measurements in the red region of the spectrum should be more rapid and shallow than measurements made in the green or blue-green region of the spectrum. Our data for large peripheral test fields with or without fixation support this finding (1,2).

Measurements of dark adaptation made within the central retina should reflect more cone function and less rod function. Anatomically, the density of cones increases towards the central retina while that of the rods decreases (7). Such is the case, as our red LED functions measured centrally are lower in threshold than comparable functions measured peripherally. Thus, increasing concentration of cone photoreceptors toward the central retina is reflected. Conversely, the increase in thresholds obtained for the green LED source reflects the general decrease in the concentration of rods as the central retina is approached.

Data obtained from individual subjects with peripheral retinal disease or congenital color vision deficiency involving long wavelength color discrimination also support the validation of this instrument. Traditional dark adaptometry made on the visual system of individuals having peripheral retinal disease always reflects greater loss in rod dark adaptation than cone dark adaptation. Our dark adaptation data for one person with peripheral retinal disease indicated more disruption in rod (green) adaptation measurements than in cone (red) dark adaptation measurements. Similarly, the one-degree dark adaptation data of our single protanopic subject reflected a greater departure from long wavelength cone dark adaptation than shorter wavelength dark adaptation in normal and congenitally color blind human subjects (2).

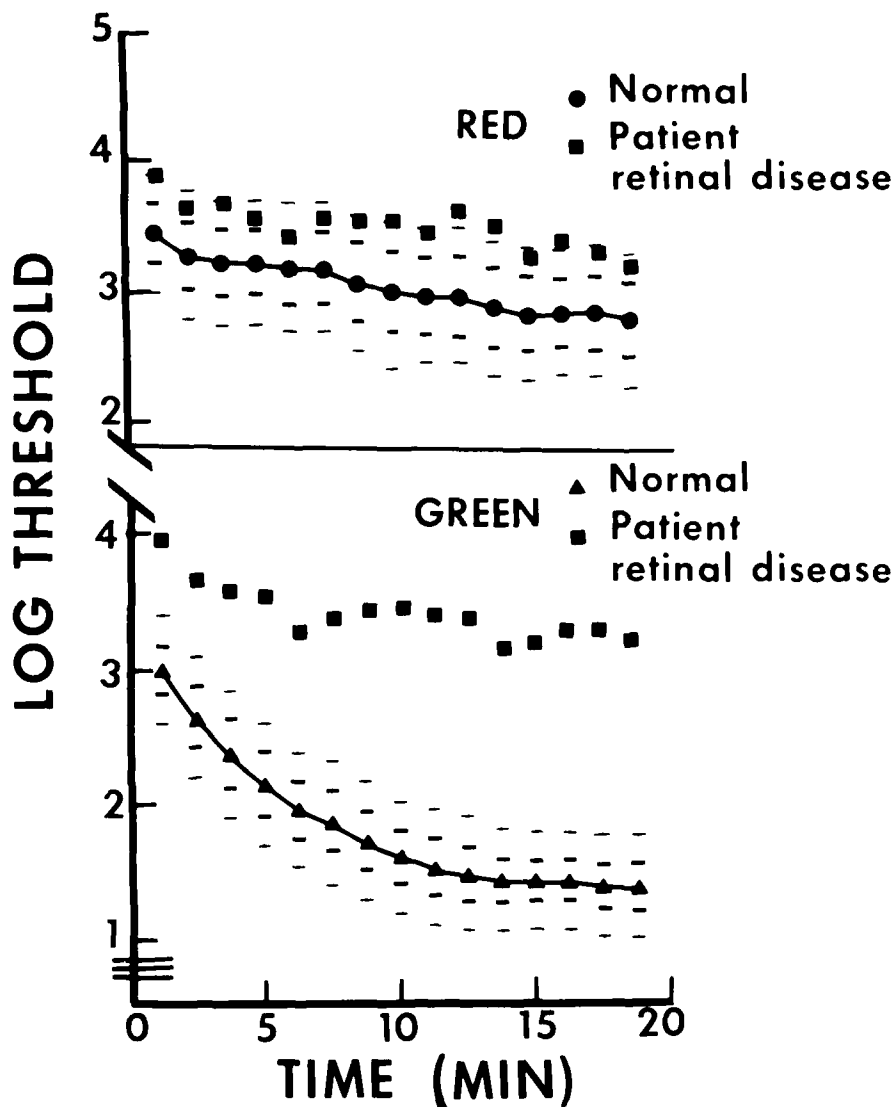


FIGURE 3. Average data from 19 human volunteers shown for both the red and green LED measured with Display 1. The inner horizontal bars represent  $\pm 1$  standard deviation and the outer bars represent  $\pm 2$  standard deviations about each mean threshold. Data from one volunteer patient with peripheral retinal disease are presented for both LED sources.

The variability obtained for our spectral dark adaptation functions is quite similar to that obtained by Sloan (8) for conventional apparatus utilizing a white light test source. As in her study, 95% of the variability in our measurements of threshold equals about  $\pm 0.5$  log units over the entire course of dark adaptation. Further comparison with the work of Sloan (8) is desirable, but comparison between a broadbanded white light test source and a spectral source is difficult. However, if her data are compared with our peripheral green LED function, as both reflect rod and cone function, the dynamic range over a comparable 20 minutes of dark adaptation is quite similar. Comparison with more recent human dark adaptation measurement made with green LED sources, where current rather than pulse modulation was used to control threshold detection, also yields a close agreement in overall dynamic range for the first 20 minutes of dark adaptation (9). Both these comparison studies measured dark adaptation out to 30 minutes and thus obtained about another 0.25 log units of adaptation. In several limited studies, we have obtained similar results, thereby suggesting that we are in fact, measuring close to the full dynamic range obtained by Sloan (8) and others (9). Furthermore, with filtered experimental short wavelength LED sources (10) we have demonstrated that the spectral components of our green LED is sufficient to evoke the scotopic system for the fully dark-adapted eye.

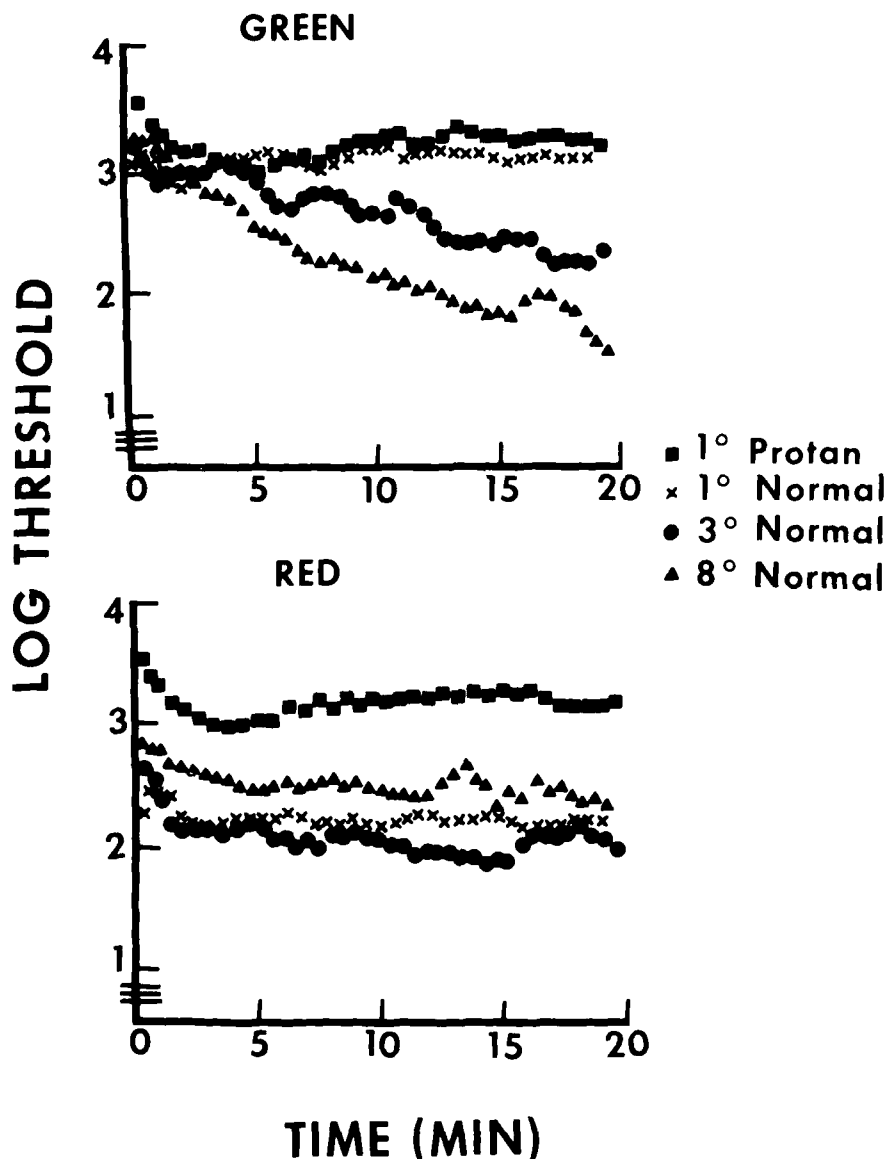


FIGURE 4. Data from one normal human volunteer measured at 8, 3, and 1 degree eccentricity from fixation as well as data from one human protan (protanope) volunteer are presented. For the normal, threshold decreases in the red as eccentricity becomes more central and increases in the green with more central eccentricity. The protan at 1 degree is much higher on the red than the normal 1 degree function. In the green, the functions for normal and protan are identical.

While the data presented here tend to validate the use of this adaptometer, its application to military night vision problems needs emphasis. Over the past two years, it has become increasingly obvious to us that even routine screening of individuals for night vision military assignment can identify individuals with severe night vision problems with underlying retinal disease etiology. While we have presented only a single case in this paper, we have made similar observations in many individuals, some of whom have been in critical positions during night vision military functions. The routine use of dark adaptometry testing to screen such individuals has obviously been greatly hampered by the complexity of the procedure and instrumentation typically associated with even the simplest dark adaptometry measurement. The LAIR adaptometer eliminates such complexity, as its computer-based format automatically plots and stores data and provides the basic options of measurement to the operator.

The associated problem of selection of those individuals that may adapt most rapidly and achieve the lowest final thresholds is a problem that can be more easily approached with an automated data storage instrument. The more complex problem of determining exactly what night vision functions are essential to overall night vision performance can be assessed best with the use of an instrument that will allow measurements of dark adaptation to be made in a varied format that offers maximum complexity of visual

measurement with maximum flexibility in experimental design. The LAIR dark adaptometer will greatly aid the applied visual scientist to resolve the present problems of optimizing night vision performance. At the same time, it will fill an important need for simple, routine capability to measure rod and cone dark adaptation in the military population.

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## APPENDIX

```

1000 REM  DEFINITIONS OF PROGRAM CONSTANTS/VARIABLES:
1010 REM  (ALL TIME COUNTS ARE MULTIPLES OF 0.1 SEC)
1020 REM      T1=LIGHT ADAPTATION TIME
1030 REM      T2=DARK ADAPTATION TIME
1040 REM      IZ=LOG UNIT DECREMENT FOR NEW STIMULUS
1050 REM      D=CONTROLS STIMULUS OBSERVATION INTERVAL
1070 REM      L( )=DUTY CYCLE COUNTS
1080 REM      P( )=100*LOG DUTY CYCLES
1120 REM      DUTY=ABSOLUTE THRESHOLD (LOG DUTY CYCLE)
1130 REM      SEC=ELAPSED TIME IN SECONDS
1140 REM      IP=ASCENDING POINTER
1150 REM      JP=DESCENDING POINTER
1160 REM      IS=8255A OUTPUT CONTROL BYTE
1170 REM      RG=COLOR SELECT, RED=0, GREEN=8
1180 REM      RL, GL=L( ) ENTRY POINTS FOR RED, GREEN TRIALS
1190 :
1200 CLEAR 255
1210 DEFINT A-Z
1220 DIM L(80), P(80)
1240 T1=3000:T2=12000:IZ=15:D=65:IP=50
1250 RL=50:GL=50:RG=8:IS=10
1310 :
1320 REM  SET UP INTENSITY TABLES
1330 FOR I=0 TO 79
1340 L=INT (2.048*EXP(.11513*I))
1350 L(I)=20475-L:P(I)=INT(100*LOG(L/2.048)/2.30259)
1360 NEXT I
1370 L(80)=0:P(80)=400
1380 :
1390 REM  HARDWARE INITIALIZATION
1400 REM  SET 8255A MODE:PORT A=OUT,PORT C=INPUT
1410 OUT 3, 139
1420 REM  INITIALIZE DUTY CYCLE TIMERS (8253, IC2)
1430 OUT 19,52:OUT 19,178
1440 REM  SET FLASH RATE TO 100 Hz
1450 OUT 16,0:OUT 16,80
1460 REM  INITIALIZE ELAPSED TIME COUNTERS (8253, IC3)
1470 OUT 11,52:OUT 11,84:OUT 11,176
1480 REM  SET 0.1 SEC TIME BASE (10*10 MS=0.1 SEC)
1490 OUT 8,0:OUT 8,80:OUT 9,10
1500 REM  SET LIGHT ADAPTATION TIME TO T1
1510 OUT 10,T1 MOD 256:OUT 10,T1\256
1520 :
1550 REM  BEGIN LIGHT ADAPTATION
1560 OUT 0,9
1570 REM  CHECK FOR END OF LIGHT ADAPTATION
1580 IF (INP(2) AND 128)=128 GOTO 1590 ELSE GOTO 1580
1590 REM  SET DARK ADAPTATION TIME TO T2
1600 OUT 10,T2 MOD 256:OUT 10,T2\256
1610 :
1670 REM  SET INITIAL DUTY CYCLE, TURN ON TARGET
1680 OUT 18,L(IP) MOD 256:OUT 18,L(IP)\256:OUT 0,15
1690 REM  INCREASE DUTY CYCLE EVERY D*0.00767 SEC (0.5 SEC)
1700 FOR I=1 TO D:IF (INP(2) AND 64)=0 THEN 1730 ELSE NEXT I
1710 IP=IP+1:IF IP>80 THEN DUTY=400:GOTO 1880
1720 OUT 18,L(IP) MOD 256:OUT 18,L(IP)\256:GOTO 1700
1730 JP=IP
1740 REM  DECREASE DUTY CYCLE EVERY D*0.00767 SEC (0.5 SEC)
1750 FOR I=1 TO D:IF (INP(2) AND 64)=64 THEN 1860 ELSE NEXT I
1760 JP=JP-1:IF JP<0 THEN DUTY=0:GOTO 1880
1770 OUT 18, L(JP) MOD 256:OUT 18,L(JP)\256:GOTO 1750
1850 REM  GET THE AVERAGE LOG (GEOMETRIC MEAN OF DUTY CYCLES)
1860 DUTY=(P(IP)+P(JP))\2
1870 :
1880 REM  TURN OFF TARGET, GET TIME, PROCESS DATA
1890 OUT 0,8:GOSUB 2370
1900 REM  STORE THE NEW LOOKUP VALUE
1910 IF RG=0 THEN RL=DUTY\5-IZ:IF RL<0 THEN RL=0
1920 IF RG=8 THEN GL=DUTY\5-IZ:IF GL<0 THEN GL=0
1930 REM  PLOT DUTY VS. TIME
1940 GOSUB 2150
1960 REM  CHANGE COLOR AND CONTINUE
1970 IF RG=0 THEN RG=8:IS=10:IP=GL:GOTO 1670
1980 IF RG=8 THEN RG=0:IS=12:JP=RL:GOTO 1670
1990 :
2010 END
2050 :
2060 REM  *****
2070 REM  SUBROUTINES
2080 REM  *****

```

7-10

```
2090 :
2150 REM PLOT RESPONSE DATA
2160 REM (THE PLOT ROUTINE IS NOT INCLUDED IN THIS LISTING)
2280 RETURN
2290 :
2370 REM GET TIME, CHECK FOR END OF SESSION
2380 OUT 11,128
2385 IF (INP(2) AND 128)=128 GOTO2010
2390 SEC=(T2-(INP(10)+256*INP(10)))\10
2400 RETURN
2440 :
2450 REM *****
```

#### DISCUSSION

DR G PERDRIEL (FR)

Although unfitness of flying personnel, through inadequate night vision, is less than 1% it is desirable to assess the extent of night vision of potential pilots. Of the adaptometers, with white or coloured light, we prefer in France to use Beyne's scotometer which measures the smallest amount of light which will permit the recognition of a shape in the dark.

AUTHOR

We are not so much concerned with aircrew as soldiers at night, for whom the ability to dark adapt or to see minimal light is extremely important. I think the fighter pilot may have a slightly different problem. We are not equating dark adaptation with night vision, we are simply saying that it is important to measure it; but we have not yet defined criteria.

## SCREENING FOR NOISE INDUCED HEARING LOSS

## IN THE NORWEGIAN ARMED FORCES

BY

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## INTRODUCTION

Screening for noise induced hearing loss serves at least three main purposes:

1. diagnosis: the detection of acquired hearing loss.
2. general prophylaxis: the establishing of risk criteria for noise exposure in order to prevent noise induced hearing loss.
3. individual prophylaxis: the judgement of individual susceptibility and chance for further development of hearing loss under continued noise exposure.

In 1979, Norway had 27.890 young men in 15 months obligatory military service and employed 25.273 full time military and civil personnel as well as about 85.000 local troops with some few weeks annual military service (Fakta om Forsvaret 1980). A hearing prophylaxis program should give individual prophylaxis against noise induced hearing loss as well as providing information relevant for the establishment and current revision of general risk criteria.

The economical means available for hearing prophylaxis in Norway are limited - and geography, climate and scattered population effectively prevent an appropriate decentralized audiological service. Consequently, the programme should allow appropriate initiatives in hearing prophylaxis to be taken locally by non-professional staff according to central decisions - as well as allowing central control of the practical results of the programme so that the needed revisions can be made, preferably by simple change of the criteria involved rather than through revision of the entire strategy. Besides, the criteria for tolerated hearing loss in the certain working environment should focus on individual permanent hearing threshold shift rather than deviation from "normal" threshold in order to avoid the massive exclusion of experience persons with already acquired hearing loss from their normal duty - provided that frequent measurements are performed, allowing the immediate suspension of susceptible individuals with progressive hearing loss from continued noise exposure.

Practical programme.

The forthcoming programme for hearing loss prophylaxis in the Norwegian Armed Forces is designed by the author and includes:

- a. A central archives of noise level registrations for the different civil and military working situations (Borchgrevink 1980a).
  1. to obtain an overview of existing noise registrations based on which one may work out a priority list of wanted registrations, saving the capacity for new measurements.
  2. allowing central audiological judgement of reported hearing loss, with the "built in" opportunity to evaluate different and corresponding working situations, evaluate and compare the different methods of noise prophylaxis applied in the various places, thus making possible a central coordination and establishment of the optimal prophylactic regimes in all corresponding working situations
  3. giving the local worker one address from where he can obtain information concerning all aspects of his noise environment.
- b. the publishing and distribution of noise level measurements, risk criteria and recommended prophylactic initiatives to the various places of work - e.g. for each type of work the minutes of noise exposure tolerated without and with recommended hearing protection before permanent hearing loss is probable, is estimated, based on the 85dB (A) Leqv. 8h noise dosage tolerance and the "3dB rule" approved by the Norwegian authorities. (Borchgrevink 1978 a,b).
- c. audiometry of personnel.
  1. enrolment of recruits for obligatory military service: screening audiometry 20dB for the frequencies 250, 500, 1000, 2000, 3000, 4000, 6000, 8000 Hz. The person is given a certain digit (1-9) depending on which frequencies he cannot hear (see C2). Certain digits are required for each type of duty, based on judgements of the operative qualifications needed for a particular service as well as the protection of individuals with susceptible hearing.
  2. beginning of work/service which implies exposure to >80dB A) Leqv. 8 h or impulse noise: screening audiometry according to C-1 and hearing threshold measurement of the standard frequencies given above on persons with > 20dB hearing loss on one or more frequencies.

Hearing measured by screening audiometry 20 dB or hearing threshold measurement.

	Normal	Hearing loss $\leq 500$	Hearing loss 1000, 2000	$> 20$ dB in freq. range (Hz) $\geq 3000$	Hearing digit
Right ear	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Left ear	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Code for selection of HEARING DIGIT: (based on screening or threshold audiometry):

HEARING DIGIT:

Normal hearing both ears	9
Hearing loss $> 20$ dB $\leq 500$ Hz one ear	
" " " " both ears	8
" " $> 20$ dB 1000, 2000 Hz one ear	7
" " " " both ears	6
" " $> 20$ dB $\geq 3000$ Hz one ear	5
" " " " both ears	4

Hearing loss 20dB in two or three of the above  
given frequency ranges in the same ear 3

Social hearing without hearing aid. The greatest sum dB loss  
for 3 neighbour frequencies (see instruction c) for right and  
left ear together is  $> 200$  dB. 2  
Lacking social hearing without hearing aid 1

Instruction (abstract):

- a) If the person's hearing loss leads to different hearing digits for the two ears, his hearing digit should be the lowest of the two digits.
- b) Hearing digit 1 implies that the person is not qualified for military service.
- c) Hearing digit 2: based on threshold audiogram one finds the 3 neighbour frequencies where the sum of dB loss is greatest for the right and left ear, respectively. Note this sum dB loss for right, left and both ears on the audiogram. Hearing digit 2 is given when this sum for both ears together exceeds 200dB and implies that the person should not be exposed to  $> 80$  dB (A) Leqv. 8h or impulse noise (aircrew still follow US standards) (Borchgrevink 1980b).

3. during work/service described in C2:

- a) audiometry as in C-2 at least annually, for recruits in the obligatory military service also after 3 months of gunfire exposure at the school for military training.
- b) In case of threshold shift  $\geq 10$  dB on one or more frequencies: repeated audiometry after one week without noise exposure, procedure as described in C2, and in case of permanent threshold shift  $> 10$  dB at one or more frequencies, eventual transfer to other work/service with lower noise exposure according to certain criteria.

4. ending work/service described in C2:

hearing threshold measurement as described in C2:

- D. Audiograms with a hearing loss  $> 30$  dB at one or more frequencies: copy should be sent to the Joint Medical Service's archives for eventual evaluation by the central audiologist.

The above program for hearing prophylaxis in the Norwegian Armed Forces is in accordance with the Norwegian 1977 law on work environment and largely also with the additional restrictions and orders that are worked out, but not yet being approved by the authorities. (Lov om arbeidervern og arbeidsmiljø 1977, Utkast til generelle forskrifter om støy på arbeidsplassen 1979). The program will be gradually introduced along with the ongoing re-establishment and reorganisation of the audiometry service, and will be subjected to revision according to future experience. The program focuses on individual permanent threshold shift, which should be a relevant parameter in hearing prophylaxis regardless of what future research might hold as the optimal parameter.

COMMENT.

Speech comprehension in noise is specifically impaired in the listener's second language, even for well known words and simple sentences (Borchgrevink 1980c). English is the main language used in aviation. We therefore work to arrive at a convenient test for first and second language sentence perception in noise, which is to be used as test for evaluation of social handicap due to hearing loss as well as adequate base for the

judgement of operational capacity in air-crew or in any personnel relying upon inter-communication systems in their duty. In the beginning the test will be used in addition to established criteria in borderline cases, e.g. for judging whether it is safe to advise continued air service in pilots with substantial hearing loss. However, there is no reason why such tests should not be used both for selection and routine examination of e.g. air-crew, as well as being introduced in the screening audiometry program for the judgement of operational capacity, as there is no convincing correlation neither between pure tone audiometry and conventional speech audiometry, nor between conventional speech audiometry and functional speech comprehension in background noise (Noble 1973, Plomp 1978, Dreschler 1980, Dreschler & Plomp 1980).

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- The author and the Institute of Aviation Medicine, P.O. Box 281, Blindern, Oslo 3, Norway tel. (02) 60 27 90 will assist the person interested in any of the above literature, which largely is not available through conventional library service.

## DISCUSSION

MR S FORSHAW (CA)

In assessing aircrew whose puretone hearing losses approach, or drop below, a given criteria level, what weight does the Royal Norwegian Air Force place on speech audiometry, particularly if the puretone hearing levels suggest that the man should be removed from flying duties?

AUTHOR

We are awaiting a speech comprehension test which is under development. At present we test the pilot's practical performance by giving him unusual, but adequate commands through the GCA operator while the pilot performs real take-off and landing procedures. If the pilot performs adequately his medical certificate is temporarily extended. In future we will probably base our criteria on a speech comprehension test rather than puretone audiometry.

PROPOSED NEW VISION STANDARDS FOR THE  
1980's AND BEYOND: CONTRAST SENSITIVITY

by

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SUMMARY

Present visual standards are generally based on the observer's ability to see small high contrast black and white letters or symbols. Current research shows that such vision tests are not adequate to evaluate an individual's target detection and recognition capability over ranges of target size and contrast used in real situations. New vision tests are being developed that use the observer's report of the visibility of sine-wave gratings (that look like fuzzy bars) to assess visual capability with much more sensitivity than that of standard tests. The new tests, called contrast sensitivity, assess vision using the same method used to assess hearing. Just as hearing tests use sound intensity and temporal frequency to measure audiometric sensitivity, contrast sensitivity tests use contrast and spatial frequency to measure visual sensitivity. Because standard eye charts do not change contrast, they cannot measure vision sensitivity to any except the smallest size symbols. The relationship between contrast sensitivity and eye charts will be discussed using normal and abnormal vision. Although standard eye charts are useful to create an in-focus image in the back of the retina, contrast sensitivity techniques are needed to measure the next physiological state that determines the observer's response to that image. Data are presented that reveal individual differences in contrast sensitivity among normal observers that have definite implications for visual performance in operational environments. Since these differences in visual sensitivity can relate to detection and recognition ranges, these data can then be transformed into time to perform certain tasks and lead naturally towards visual standards being based on task performance under operational conditions. It is suggested that contrast sensitivity data be obtained in parallel with conventional vision tests to begin creating visual standards that relate to observer capability over the full range of operational environments.

INTRODUCTION

The Air Force mission is to fly and fight. Although manned aircraft are projected to perform that mission well into the twenty-first century, today's high technology aircraft are outperforming the physical capabilities of the pilot and are creating increased workload that can seriously jeopardize the success of the mission. These facts demand the selection of pilots based on physical standards that complement his weapons systems and call to question currently accepted standards in many areas. One obviously important physical standard relevant to virtually all Air Force missions is vision. Although no one would question the importance of other complex tasks that the pilot is required to perform, vision is the only sensory system to be used to its fullest capacity. In spite of advanced electro-optical sensors, visual target acquisition remains the key to successful air-to-air combat. He who detects the enemy first has by far the greatest chance of survival and combat success. That dictum, echoed throughout aviation history, was recently reinforced by written comments obtained from 100 American air aces (1). That study also found that visual target acquisition was rated as a more important critical combat skill than selecting and executing the best maneuver to gain a firing position. Further, superior vision can reduce workload. Increased detection range of targets means increased time for the pilot to perform combat related tasks which in turn help reduce workload. In summary, present and future missions will require pilots to have optimum visual capability and visual standards must relate to that capability in terms of task performance.

Although no one would regard visual target acquisition as a simple function, current visual science does allow that complex function to be broken down into certain general subfunctions; for example, optical, physiological, and cognitive. Even these subfunctions are complex and the relationships between them are not fully understood. However, at least certain major aspects of the first two functions--optical and physiological--appear to be understandable and measurable today to the degree that meaningful standards for those functions can be considered. These two functions will be discussed and related to the possible creation of relevant visual standards based on observer capability that effect combat performance. This approach does not diminish the importance of cognitive factors in target acquisition. However, unless the optical quality of the eye creates an in focus image at the retina and physiological mechanisms are sensitive to features of that image, then it is a moot point as to the motivation of the observer affecting performance. No amount of motivation can make up for the fact that the target cannot be physically seen. It is highly unlikely that complex visual performance will ever be fully predictable in the real-world except for certain limited tasks under special conditions. Until further gains are made in understanding complex visual function, it is suggested that our present goal be to set standards that optimize the capability of visual functions that can be measured and are known to consistently affect performance.

The stress on general capability rather than specific performance is made because all too often visual standards as well as other performance criteria are required to be shown

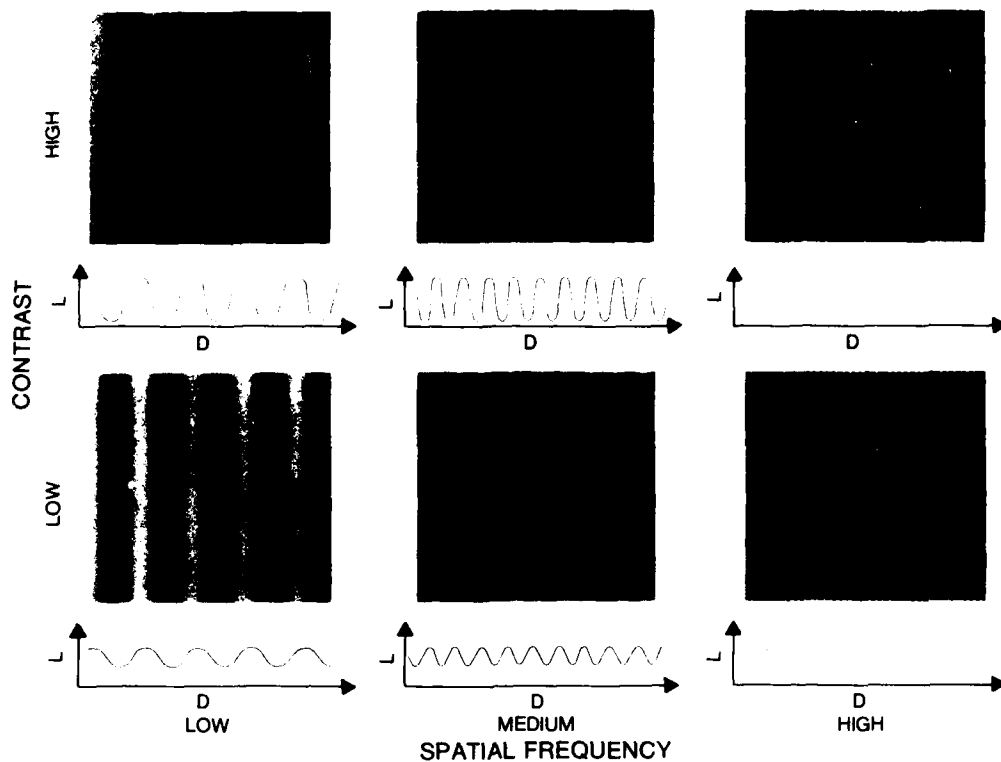


Fig. 1 Examples of sine-wave gratings having low, medium and high spatial frequencies at low and high contrast. The luminance distribution for each grating is shown below each grating patch. Note that these gratings will have different visibilities depending upon viewing distance due to the visual filtering characteristics of the observer. (from ref. 22)

relevant to "real-world" performance before acceptance. On the surface, that requirement seems quite reasonable. The main problem with that approach is that there is an endless list of "real-world" performance criteria that are based upon sometimes quite different mission requirements. Relevant visual requirements for the combat pilot to detect a target under clear atmospheric conditions over a desert are quite different from that under low contrast conditions such as those found in haze, fog or smoke that would exist in a European scenario. Present needs require visual standards that relate to visual capability that are needed under all possible viewing conditions.

Present visual standards are primarily based on measures of visual acuity using the visibility of high contrast optotypes such as Snellen letters. Unfortunately, visual acuity measures based on high contrast targets have not related well to visual performance except under certain conditions of limiting resolution. By definition, acuity measures do not measure visual sensitivity over the range of object size and contrast that is relevant to many combat arenas; for example the relatively high contrast environment of the daytime desert as compared to the low contrast European environment seen under twilight or dawn conditions. However, the limitations of acuity measures can be overcome using a more sensitive measure of visual capability: contrast sensitivity. This paper will present data that show the limitations of acuity measures and the advantages of contrast sensitivity to help create vision standards that do relate to the capability of performing certain military missions. For example, individual differences in contrast sensitivity exist that have important implications for visual target acquisition under a wide variety of conditions that are not measured by acuity tests. Finally, the

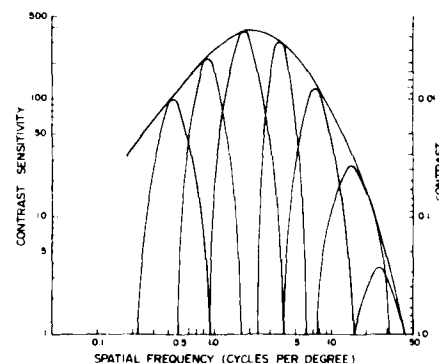


Fig. 2 A typical threshold contrast sensitivity function (15) is shown by the wide-band inverted U-shaped curve. Note that the visual system is most sensitive to threshold sine-wave gratings at about 2 cpd and is limited to passing spatial frequencies greater than about 60 cpd. The narrow-band curves represent channel filters based on biological data (12).





Fig. 3 A photographic series of a F-16 aircraft having decreasing contrast. Note that the details such as the wing-tip missiles disappear before the larger features such as the wings and fuselage with decreasing contrast. Similar to the gratings of Figure 1, note that the features of these aircraft will have different visibilities upon viewing distance due to the visual filtering characteristics of the observer.

implications of contrast sensitivity on target visibility, detection range and workload will be discussed.

#### PRESENT VISUAL STANDARDS: VISUAL ACUITY

The first visual capability relevant to target acquisition is good optical quality; to have an in-focus image at the back of the retina. This capability of vision, by far the main criterion of all present visual standards, generally uses acuity measures to determine the optical quality of the retinal image. High contrast optotypes are typically used to measure visual acuity usually in terms of resolution of gaps in Landolt rings, the orientation of letter E's or the legibility of Snellen-type alphanumeric characters. The basis for these tests is retinal sampling: intercone spacing of the retina limits visual acuity. These anatomical considerations lead to the notion that the retina, having an in-focus image, should be able to resolve approximately one minute of arc. Snellen-type characters are formed on a 5x5 element grid. Snellen line 6/6 (20/20 in feet) refers to the visibility of the size of targets that subtend five minutes of arc at a distance of 6 meters, each target having stroke widths that subtend one minute of arc. Good visual acuity is generally defined when an observer can perform the resolution or recognition task using the fine detailed information from Snellen line 6/6 to 6/12. These types of acuity tests have certain distinct advantages. The patterns are simple to make since

they have only one black and white level. They are simple to use, requiring no expertise on the part of the administrator and with certain tests, no expertise required from the subject. They are relatively quick and in most cases accurate to generally accepted standards. Further, the prints or slides that are used are relatively low in cost. Historically, acuity measures have been successful in helping refract the majority of eyes. These reasons suggest why Snellen-type acuity measures are widely accepted. However, even with all these advantages, the distinct disadvantage to these techniques is their limit in being able to provide a measure of visual quality that relates to performance under most visual conditions. The fundamental assumption of the acuity measure is that the optimum optical quality of the retinal image insures optimum visual performance. However, by definition, an acuity measure can only give a single number that relates to limiting performance and can address little about visual performance up to that limit. Further disadvantages include the nonstandardization of conditions under which acuity measures are obtained throughout the world. It is well known that such factors as pupil size and level of illumination can effect visual acuity. Further, different kinds of optotypes require different amounts of resolution ability. These factors make acuity standards difficult to control and interpret. It is little wonder that the operational community balk at visual standards based on a single number that can so drastically effect a person's career. Recently, there has been an attempt to provide standard procedures for the clinical measurement and specification of visual acuity (2). Even before other visual standards are considered, it seems as a minimum that the Armed Forces should standardize procedures for the measurement and specification of visual acuity.

It should be remembered that clinical optotypes are primarily used to determine the optical quality of an individual which in turn is used to determine whether corrective lenses are required or not. The optotypes allow simple determination of whether an image is in or out of focus. An out-of-focus image causes the optometrist and ophthalmologist to attempt to correct the optical transfer function of the visual system. Since the optical transfer function of the visual system is a relatively simple linear function, then the correction of any one point of that transfer function will maximize the correction at all the other points. Thus, the types of measurements and specifications for optimizing the optical quality of the eye have been relatively relaxed. However, those same relaxed conditions can cause certain differences in final acuity measurements which could play havoc with studies that require consistent measures of visual acuity. Since acuity measures were designed to explicitly relate to optical quality, provide only a measure of limiting resolution under high contrast conditions, and are not standardized, it is little wonder that they do not relate well to visual performance under most conditions.

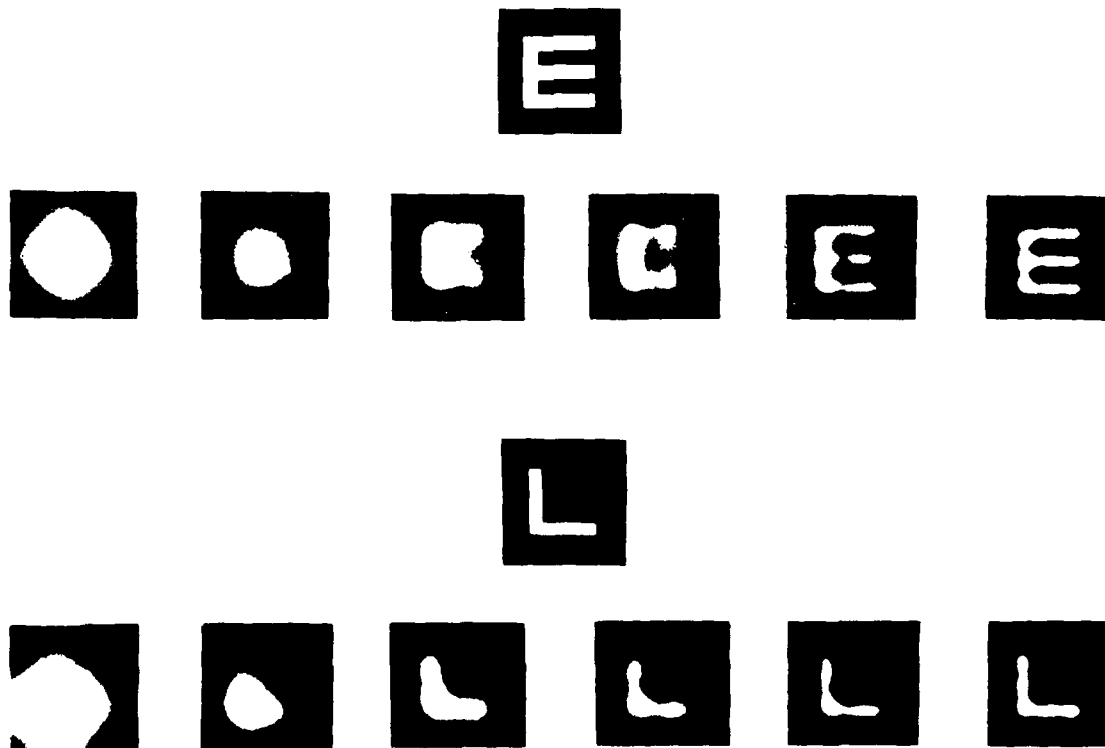


Fig. 4 Fourier synthesis of Snellen letters E and L in increments of 0.5 cpl. The synthesized filtered images of the E and L are shown below their respective letters: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 cpl. (from ref. 12)

If on one hand there are many factors that effect visual acuity, this is balanced on the other hand by the fact that superior visual acuity evidently does not play an important factor in much of what we see. Although this may seem a bit paradoxical, our everyday perception provides many examples that much of our visual processing does not require information about the finest detail contained in objects. It is not uncommon for an optometrist or an ophthalmologist to find individuals that have not reported visual problems that require one or two diopter correction. Although we certainly want the highest degree of visual quality for the pilot performing target acquisition, since initial detection is of prime importance for successful combat, we should also be aware that it is only one facet of visual perception that must be considered and other factors such as sensitivity to larger objects having lower contrast are more relevant for most viewing conditions.

Another important factor relevant to optical standards is whether or not optical aids can be used in the combat environment. Although one would argue for dissimilar optical quality between an observer having 20/20 with or without corrective lenses, (excluding of course large magnification changes) there are distinct disadvantages to wearing certain optical aids in the operational environment (3). Standard eyeglasses, for example, will become quite heavy under the high Gs reached in air-to-air combat, they are also subjected to lint, haze, glare, slippage, and sweat, not to mention possible loss that can interfere with performance. Further, the frames of conventional glasses obscure targets at certain visual angles. The use of contact lenses is also prohibitive for similar kinds of reasons. An additional negative factor of contact lenses is of course the possible presence of dirt or other substances beneath the lense causing irritation. However, with a more optimum design of

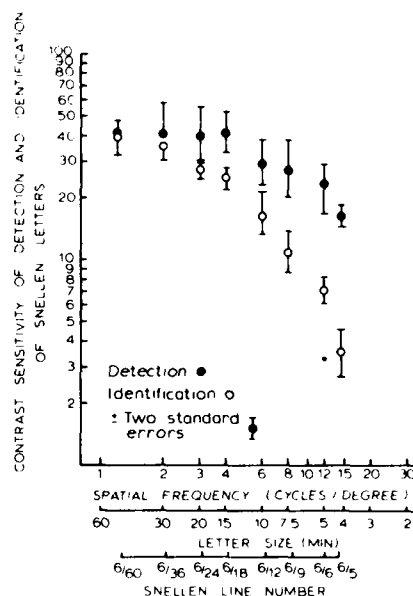


Fig. 5 Contrast sensitivity for the detection and identification of at least 50% of the Snellen letters on each line of a typical Snellen chart. The contrast sensitivity is the reciprocal of the threshold contrast needed for detection and identification of the letters. The spatial frequency ( $f$ ) is the fundamental spatial frequency or 1 cpl for the letters on each Snellen line ( $f=60/\text{size of letter}$ ). The Snellen line number is given in meters. Snellen lines 6/60 and 6/6 are similar to 20/200 and 20/20. These contrast sensitivity values will change somewhat due to field size and average luminance and should not be taken as absolutes. (from ref. 12)

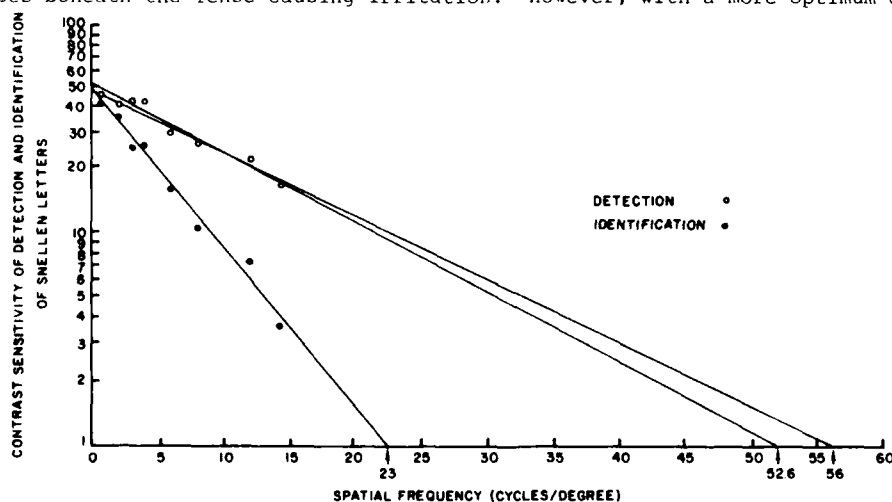


Fig. 6 Contrast sensitivity for the detection and identification of Snellen letters shown in Figure 5 replotted using log-linear axis. Regression lines drawn through the data points are extrapolated to the x-axis. The two different lines through the detection data exclude and include the first three data points at peak sensitivity respectively. The similarity of these detection results suggest that the data obtained after peak sensitivity will give reasonable results relatively independent of changes in peak sensitivity. The spatial frequency bandwidth required to go from detecting to identifying these letters is  $56/23=2.4$  cycles per letter width. (from ref. 12)

corrective lenses, it is possible that the problems associated with present glasses can be eliminated or at least minimized.

In summary, the optical quality is the first important step that one must deal with in optimizing visual target acquisition. Present visual standards should be dictated by the importance of initial target acquisition in combat. Thus, visual standards in terms of optical quality should be as high as possible, taking all other performance factors into consideration. Finally, standardized procedures for measuring and specifying visual acuity should be created. However, the creation of an in-focused optical image is but the first stage of vision and the next stage of visual processing which deals with actual detection and other perceptual processes must be considered. This next stage deals with sensitivity of the physiological retina-brain system that uses the optical image created at the back of the retina for subsequent target acquisition.

#### PROPOSED VISUAL STANDARDS: CONTRAST SENSITIVITY

Over the past decade, an alternative method of testing vision has come into use in both the scientific and clinical communities that measures visual sensitivity using targets called sine-wave gratings that are specified in terms of two variables: spatial frequency and contrast. Schade (4) pioneered the use of spatial frequency and contrast as a means of assessing spatial vision. Since then, a number of significant contributions have been made by other researchers --DeLange (5); Lowry and DePalma (6); Westheimer (7); Kelly (8); Robson (9); Campbell and Green (10)--that have led to present methods for measuring contrast sensitivity. A sine-wave grating is a repeated sequence of light and dark bars whose luminance profile varies sinusoidally about a mean luminance with distance. The width of one light and one dark bar of a grating is one cycle, or the period of the grating. The reciprocal of the period is the spatial frequency. Spatial frequency is expressed by the number of cycles of the grating that occur over a particular distance. The spatial frequency of an object can be expressed by cycles per object (CPO) dimension or, more commonly, by cycles per unit of visual angle. The number of cycles per object dimension is called normalized spatial frequency. It is determined by the size of the particular dimension of some part of the entire object and is independent of viewing distance. Cycles per unit of visual angle, more commonly called cycles per degree (cpd), is determined by the viewing distance. The luminance difference of the light and dark bars determines the contrast of the grating. The Michelson definition of contrast is most often used:

$$C = \frac{L_{\max} - L_{\min}}{L_{\max} + L_{\min}}$$

where  $L_{\max}$  and  $L_{\min}$  are the maximum and minimum luminances of the bars of the grating. Examples of sine-wave gratings having low, medium, and high spatial

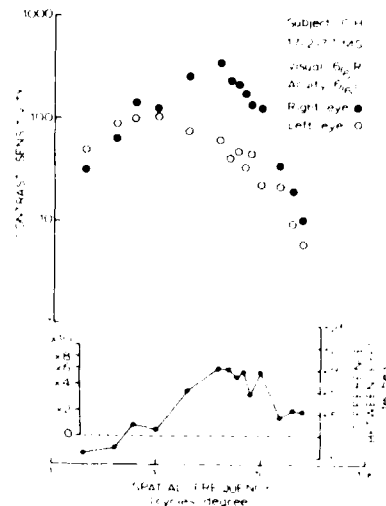


Fig. 7 The contrast sensitivity functions of each eye from a patient having multiple sclerosis. This patient complained about the poor quality in the left eye even after it was tested to have normal Snellen acuity. The complaint was real as evidenced by the difference in contrast sensitivity between the eyes shown in the upper and lower (the visigram) curves. This dramatically shows the poor ability of Snellen-type measures to determine the general quality of spatial vision. (from ref. 12)

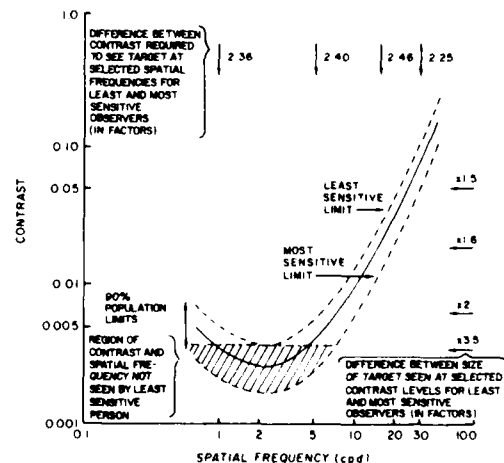


Fig. 8 Average threshold contrast to detect disks and sine and square-wave gratings is shown by the solid line. The dashed lines are 90 percent population limits. See text for explanation (after ref. 20)

frequencies at low and high contrast are shown in Figure 1. The luminance distribution for each grating is shown below each grating patch.

If the contrast of a grating is increased from below its visibility to where the grating is just seen, then the grating is said to have reached threshold contrast. The reciprocal of the threshold contrast is called contrast sensitivity. Gratings of different spatial frequencies require different amounts of contrast to reach threshold for the observer. In a typical measurement session for contrast sensitivity, a subject adjusts the contrast of a sine-wave grating until the bars are just at the threshold of visibility. Measurements are repeated for a number of bar widths (spatial frequencies). The reciprocal of contrast threshold is plotted as a function of spatial frequency to create a contrast sensitivity function. A typical contrast sensitivity function is shown in Figure 2. The broad, inverted U-shaped curve describes the visual "window" which limits the range of size of objects that can be seen under conditions of threshold contrast. The area above the curve is the region of low contrast where the visual system does not see objects as it is below threshold. Note that the visual system is most sensitive to sine-wave gratings at about 5 cpd depending upon experimental conditions. Sensitivity decreases for spatial frequencies above and below peak sensitivity. As with auditory processing of temporal frequencies, only a limited range of spatial information can be passed by the visual system. The physiological limit is about 60 cpd which depends upon viewing conditions. There are also techniques for obtaining suprathreshold contrast functions but that discussion is beyond the scope of this paper. The more narrow curves shown within the contrast sensitivity function represent relatively narrow bandwidth mechanisms called "channels" that make up the overall contrast sensitivity function. These channels are suggested to play a major role in "filtering" relevant target information such as contrast, size, and basic form (11, 12). Evidence for these channels and their relationship to visual perception is also beyond the scope of this paper. However, references 12 and 13 are suggested for the interested reader.

There are three general techniques currently used to measure contrast sensitivity to gratings: electronic generation for TV displays (10), film (12), and photographic plates (14). The TV displays provide the most accurate measurements; however, high levels of expertise in electronics, display technology, and/or computer hardware and software are required for best results. Gratings created on film can be imaged by standard projection techniques and their contrast can be controlled by polarizers (12). The major requirement of this approach is being able to create high-quality sinusoidal gratings and other targets on film. Unfortunately, the precise alignment of the optical components makes portability difficult without realignment. The third technique that uses photographic plates also has problems of poor reproduction of gratings and large operator biases. Variations of these three techniques are being used and improved in the Aviation Vision Laboratory. In particular, research is on-going to create portable devices for measuring contrast sensitivity.

The importance of contrast in enabling one to see various spatial information in objects cannot be stressed too much. The loss of spatial information in objects as reduced is demonstrated by the F-16 aircraft shown in Figure 3. Various details about the aircraft, such as the wing-tip missiles, are selectively lost as the contrast is reduced from 100 percent to about 6 percent. At the lowest levels of contrast, only a cigar-like shape remains. This series of pictures depict the amount of visible detail that could be expected to be seen as a target flies into haze or clouds.

There are two main attributes of the contrast sensitivity test. First, since contrast is the depth of modulation of the grating about an average luminance, the average light level is kept constant resulting in a constant state of retinal adaptation. This greatly reduces nonlinearities in measuring contrast sensitivity due to the eye being at different stages of adaptation. It has been shown that the contrast threshold (15), and more recently certain aspects of perceived suprathreshold contrast (16, 17) are approximately linear. A high degree of linearity of processing spatial information allows the use of well-defined and easily implemented mathematical techniques to explain how objects are seen, whereas nonlinear processing greatly increases analytical complexity. Second, sinusoidal gratings are linear basis functions. This means, in mathematical terms, the single sine-wave grating is a very simple stimulus. It is one-dimensional and contains one frequency. Using Fourier techniques, any complex object can be broken down or built up from a combination of spatial frequencies having different amplitudes and orientations.

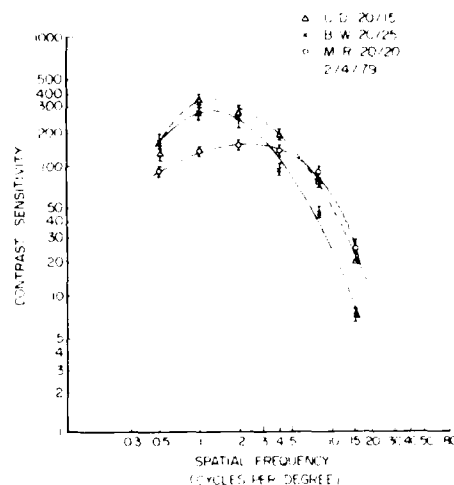


Fig. 9 The contrast sensitivity functions of three pilots. Although pilots CD and MR have normal Snellen acuity (shown to the right of their initials), significant differences in their contrast sensitivity below about 7 cpd are found. These differences may have important consequences for task performance, as discussed in the text. (from ref. 22)

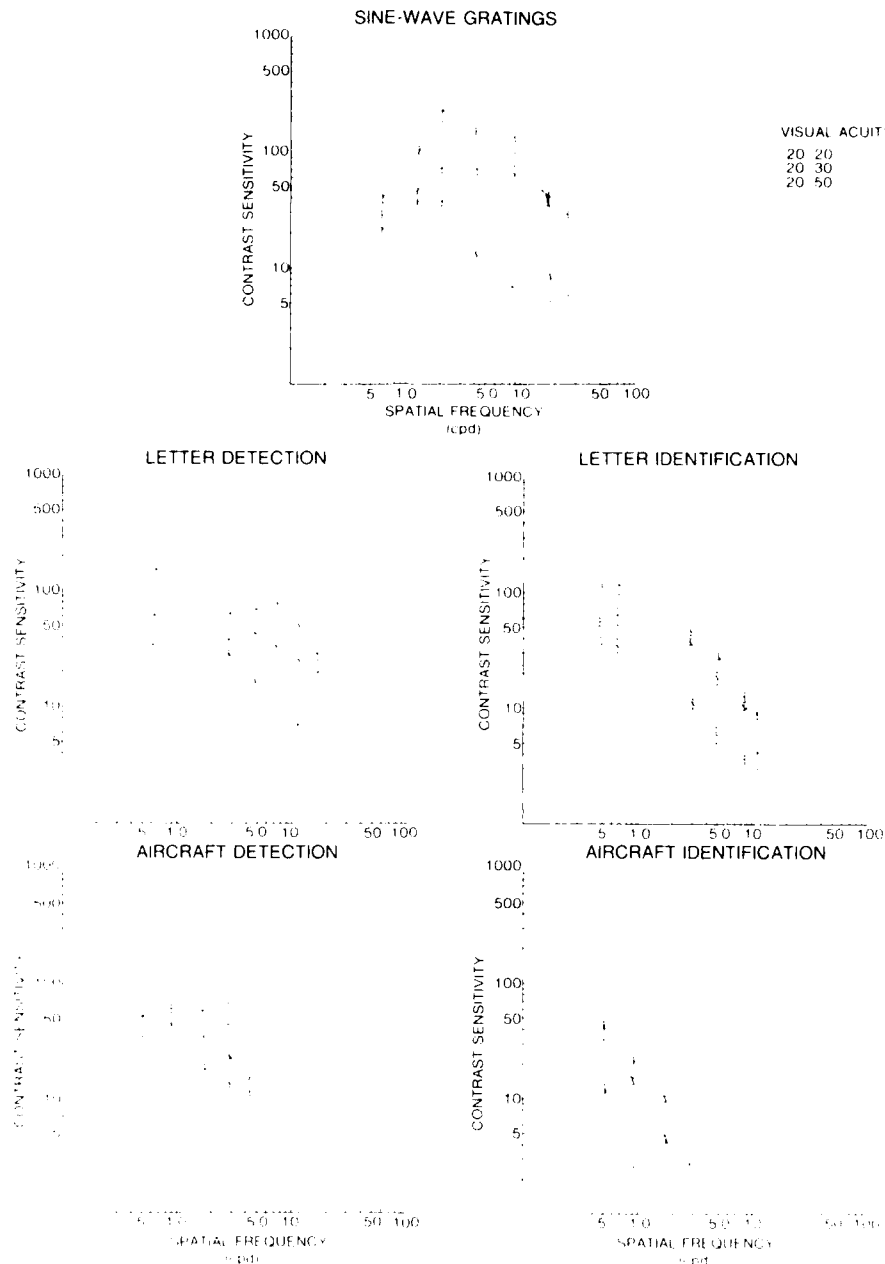


Fig. 10. Contrast sensitivity to sine-wave gratings, and detecting and identifying letter and aircraft silhouettes for two subjects having 20/50 and 20/30 Snellen acuity without their glasses and one subject having normal (unaided) Snellen acuity. (See text for explanation (from ref. 23).)

It seems that the spatial information in high contrast optotypes or any target can be determined from combinations of single gratings, as will be shown later. If certain assumptions are accepted that are beyond the scope of this paper, then the contrast sensitivity function, which represents the general filtering characteristics of the visual system to sine-wave gratings, can be used to determine the visibility of any complex object (12). Two-dimensional filter characteristics of the visual system can also be obtained from a combination of contrast sensitivity functions of one-dimensional gratings determined at a number of orientations; for example, at angles of 45, 90, and 135 degrees. This type of filter can also be used for predictions of visibility of objects (18). This approach provides a powerful, unifying basis for research into complex target acquisition and simple filter functions based on visual data. Moreover, this approach, since it uses the same language used by engineers, allows a natural step to be taken to determine relevant spatial information presented to observers for display design and image quality (19). Finally, the contrast sensitivity approach is becoming a more widespread tool among scientists with which to probe vision. Many factors which affect the shape of the contrast sensitivity function have been studied. For example, the effects of luminance, focus,

field size, peripheral view, chromaticity, and others have been measured (20). Thus, much is known about the general behavior of contrast sensitivity functions under operationally relevant conditions. Basing visual metrics on these techniques will allow quick integration of knowledge in current science into applied areas.

Although contrast sensitivity appears to provide a more complete measurement of spatial vision than acuity measures, unless the filter characteristics can be used to relate visual capability to visual performance such as target acquisition, then its power will be limited. What is needed is a relationship between contrast sensitivity and the visibility of complex objects. That relationship is presented next.

A general relationship between contrast sensitivity and the visibility of Snellen letters has been determined (12). It is pointed out that Snellen letters represent a set of overlearned complex two-dimensional targets. Two pieces of information were needed to establish that relationship: the minimum number of spatial frequencies and the minimum contrast required for the recognition of Snellen letters. The number of cycles necessary for the recognition of Snellen letters was determined by Fourier synthesis of a letter L and a letter E, in steps of 0.5 cycles per object (cpo) as shown in Figure 4. These letters were chosen because the E is more difficult to resolve than the letter L. First note that the energy contained in the frequencies below 1 cpo allows detection to occur but not recognition. For recognition to occur, 2.5 cycles are required for E, but only 1.5 cycles are required for the L. It should be clear that this is the reason for the L being recognized at a greater distance or smaller angular subtense than the E. These results suggest that a bandwidth (the relevant number of spatial frequencies for a particular task) of about 1.5 to 2.5 cpo is required for the recognition of Snellen letters (12, 21). It is important to note that this result would not be intuitively obvious from using resolution criteria of visual acuity. For example, previous attempts to relate Snellen acuity to contrast sensitivity did use the visibility of stroke width as criteria for recognition. For Snellen letters, the stroke width is one minute of arc, which equals 30 cpd. That analysis suggests the recognition of the Snellen letters should occur when the letter stroke is visible, i.e., when contrast is great enough to allow the frequency of 30 cpd to reach visual threshold. However, it is well known that L is more visible than an E. Therefore, this very common approach used in much previous research can lead to wrong conclusions about spatial information in objects used for target acquisition. These results show that it is the two-dimensional distribution of the target features that determines their visibility.

The next step related the relevant spatial frequencies required for recognition to the contrast sensitivity of the visual system to those spatial frequencies. That required knowledge about the minimum level of contrast (contrast threshold) for the detection and recognition of letters subtended at the different visual angles that correspond to the different size letters for each Snellen line. Those results, using typical Snellen letters, are shown in Figure 5. For large Snellen letters, note that detection and recognition thresholds are very similar. The everyday experience of this is a person or an object appearing suddenly out of fog at close range or a pilot flying through smoke, haze, etc. However, for small Snellen letters, there is a large difference between the detection and recognition. The smallest letters used, Snellen line 6/5, requires a factor of about 4 to 5 in contrast from detection to recognition. We have all experienced this effect, even in conditions of good visibility, when we detect an object easily but find we must get very much closer for correct recognition. A more relevant example is a pilot who detects a target at 20 miles but travels 10 miles before correct recognition occurs.

Another way to look at the finding that certain large objects can be recognized as soon as they are detected under low contrast conditions is in terms of the bandwidth of cycles per object necessary for this task. Large Snellen letters whose overall size is 60 minutes (1) of arc have a fundamental frequency of one cycle per degree. The 1.5 to 2.5 cycles per letter necessary for recognition occur at spatial frequencies from about 1.5 to 2.5 cpd. The typical contrast sensitivity function Figure 2, shows that these spatial frequencies are all at or near peak visual sensitivity. When the relevant frequencies required for detection reach threshold near peak sensitivity, the spatial frequency components in the bandwidth required for recognition, having spatial frequencies up to about 2.5 cpd, are also reaching threshold at about the same time. Thus, the spatial frequencies used for detection and recognition of these targets reach threshold almost simultaneously. However, note that a letter on Snellen line 6/6 has a size of five minutes, corresponding to a fundamental frequency of 12 cpd. The 1.5 to 2.5 cycles for this letter corresponds to 18 to 30 cpd. Thus detecting at or below 12 cpd now requires 4 to 5 times more contrast in order to get the spatial frequencies from 18 to 30 cpd above threshold or recognition can occur. It should be noted that certain targets can be created such that detection and recognition can occur simultaneously at any distance (12).

The bandwidth required for recognition of Snellen letters determined from the filtered letters of about 1.5 to 2.5 cycles per letter can also be determined directly from these data. By replottting Figure 5 in terms of log contrast sensitivity versus linear spatial frequency, shown in Figure 6, note that the regression lines provide the bandwidth used for detection and recognition. Depending upon the particular spatial frequency at which the peak of the contrast sensitivity occurs, the bandwidth is about 2.4 cycles per letter. This result confirms the earlier filtering results of these letters. Further, these methods provide a general paradigm with which to determine the relevant bandwidth of spatial frequency information in any target from detection to classification, recognition, identification, and discrimination. Note that the regression line that excludes the data at contrast near peak sensitivity crosses the spatial frequency axis at 36 cpd, very near the physiological limit of 60 cpd. This technique can be used to provide a very

sensitive measure of an individual's limit of visual acuity. Thus the basic data required to make predictions of Snellen acuity from contrast sensitivity measurements have been obtained: the amount of contrast and the relevant spatial frequencies of these objects necessary for recognition. Validation studies of this approach have been conducted. Highly unusual contrast sensitivity functions from patients having amblyopia (a dimness of vision that cannot be corrected by optical means) and multiple sclerosis (a neurological disorder that affects vision) were determined and used to test the predictive power of this approach. In sum, based upon the contrast sensitivity of individuals having those visual disorders, the Snellen acuity of 17 to 22 eyes could be predicted within one Snellen line, the other 5 eyes predictable within two Snellen lines (12,22). Thus these data suggest that the contrast sensitivity function can be viewed as a filter that can predict the visibility of complex targets.

One robust future of this research is that the contrast sensitivity function can predict poor visibility of certain patients when Snellen acuity predicted normal vision. For example, the contrast sensitivity function shown in Figure 7 is from a patient having multiple sclerosis (MS) who complained about the quality of vision in one eye compared to the other. This patient, using Snellen acuity, was measured as having normal or 6/6 vision. However, the contrast sensitivity between the two eyes is about a factor of 4 over almost a factor of 10 range of spatial frequency. Why is Snellen acuity not measuring this obvious difference in sensitivity between the eyes? The answer comes from the previous discussions. It was shown that 6/6 vision needs a certain amount of contrast sensitivity from about 18 to 30 cpd. A closer examination of the contrast sensitivity function of this patient having MS shows sufficient contrast in both eyes over the range of spatial frequencies required for 6/6 acuity. This result shows that Snellen acuity is not measuring sensitivity to obviously important ranges of object size less than about 18 cpd because the Snellen letters have only one level of high contrast. Similar results showing the inadequacy of Snellen acuity have also been found by others (2,2). The message is clear. Snellen acuity is not measuring the degree of visibility of objects over large range of sizes because it does not take into account visual sensitivity to contrast. The auditory equivalent to Snellen acuity is to use only one high level of loudness for all sound frequencies tested. The sensitivity to sound would be measured from only 12khz to 20khz, excluding very important sensitivity to sound frequencies from 50khz to 12khz. Limited measurement in vision should not be accepted any more than limited measurement is accepted in audition.

The reason that Snellen acuity and other types of resolution criteria have been reasonably successful in both the measurement and correction of spatial vision is understandable. As previously pointed out, Snellen acuity can be used successfully for refraction because the vast majority of visual problems are optical in origin. Since the transfer function of an optical system is, in general, well behaved, the measurement of one point can be used to determine the performance over a large range of other points. Using a lens to correct one point for Snellen acuity will, in general, increase the visibility of objects at all the other points. However, if there are physiological differences in sensitivity or a visual deficiency is neurological and/or visual conditions are such that the measured resolution limit is not being used and an observer is forced to use lower spatial frequencies and contrast, then visual quality cannot be determined by resolution measures alone. That is why certain patients complain about poor visual quality that is tested normal using Snellen acuity.

#### CONTRAST SENSITIVITY AND TARGET ACQUISITION

It has been shown that Snellen acuity does not measure visual sensitivity below about 18 cpd. This means that the relative visual sensitivity between pilots or other observers to reduced contrast targets whose size is larger than about 3.3' is not known. Normal Snellen acuity means that targets whose size is larger than 3.3' can be seen at any level of contrast. However, any conditions that reduce target contrast to the pilot, for example, low target-to-background contrast, atmospheric and windscreen haze, smoke, clouds, rain, fog, or certain chemicals, force vision to use lower spatial frequencies to which visual sensitivity is not being measured using current vision tests and thus is not known. A similar situation exists for display operators, photointerpreters, x-ray diagnosticians and any other observers when their visual tasks are performed under similar reduced contrast conditions.

Unfortunately, there are no definitive population studies of contrast sensitivity data that can be used to determine the degree of differences in sensitivity that could be used to relate to the ability to visually acquire targets. One conservative set of data is available, however, that can provide at least a first approximation to individual differences in a normal population. One study determined population estimates of average contrast sensitivity measurements (20). The average contrast sensitivity function was a "best approximate fit to the better visual performance data" of eight different factors. The performance was measured in terms of threshold contrast modulation for foveal and parafoveal parafoveal targets. These data are shown in Figure 8. Here threshold contrast is defined rather than threshold contrast sensitivity. The solid line is the average "best fit" data. The dashed lines are limits for 90 percent of the population. The maximum percentage values of threshold contrast from these data for 1, 5, 10, and 30 cpd are shown. The average difference of 2.36 in sensitivity exists for 90 percent of the population. Note that the difference in sensitivity changes with spatial frequency. The greater the sensitivity, the smaller the target that can be seen at the same distance. The expected visual performance for low contrast targets of two observers, one having the lower sensitivity curve and the other having the higher sensitivity curve can, in general, be understood from the figure. The more sensitive person will see, on average, and if all other factors are



held constant, the same size target 2.15 times further, or a target 2.15 times smaller at the same distance, than that of a less sensitive person. In particular, the more sensitive person can see a low contrast target at 7 cpd when a less sensitive person can see the same target at 2 cpd and cannot see similar contrast targets smaller than 2 cpd. In terms of target size, this means that a less sensitive person is just seeing a 30' size target when a more sensitive person is seeing an 8.6' target, 3.5 times smaller in size. The more sensitive person will see a 30' size target 3.5 times further (or more easily, i.e., higher signal-to-noise ratio in case of photointerpreters and display observers) than that of a less sensitive person. Indeed, the cross-hatched region shows certain levels of low contrast where the more sensitive person can see targets ranging in size from about 0.5 to 8 cpd or 2' to 7.5' when the less sensitive person cannot see targets of any size. These are the maximum differences that can be postulated from this study. The difference in sensitivity decreases for higher spatial frequencies or smaller target sizes. For example, at 20 cpd or for a 3' size target, the increased sensitivity results in increased target size by a factor 1.5. These increased distances of target acquisition could provide increased time for a pilot to use to optimize tactics and other combat related tasks, and thus can help reduce workload.

The preceding analysis suggests that there are important differences between visual observers that have different contrast sensitivities that have direct implications for the selection of pilots and others whose visual ability are important for task performance. It would seem that observers having increased contrast sensitivity will be capable of acquiring targets further away than less sensitive observers under certain circumstances. Furthermore, this analysis may provide a basis for understanding and quantifying the quite common anecdotal comments about superior visual performance of "air aces." It is important to note that the conservative difference of a factor of 2.5 in contrast sensitivity between a high sensitive individual and low sensitive individual has definite implications for target visibility. For example, as previously mentioned, only a factor of 1.5 to 2.0 increase in contrast is needed to go from chance detection to almost certain detection. This means that, when all other factors are held constant, the high sensitive observer is certain that a target is detected when the low sensitive observer may still be guessing. Further, there is about a factor of 2.5 between the contrast of the lightest and darkest features of the F-16 aircraft in Fig 3c and that of Fig 3e. Therefore, there will be conditions where a high sensitive observer may be able to identify the aircraft and know in what direction it is headed when the low sensitive observer is only able to see a cigar-shaped object. Clearly, these differences in visual capability are very important in today's combat environment when split-second decisions mean the difference between success or failure of a mission.

The next stage in this research has been to investigate the degree of variability in contrast sensitivity among Air Force populations. Only small population studies have been obtained to date. However, interesting individual differences have been revealed. For example, the contrast sensitivity functions shown in Figure 9 are from three pilots (22). Although each pilot has good Snellen acuity, there are significant differences in sensitivity over different ranges of spatial frequency. Pilot M.R. would be more sensitive to low contrast objects whose relevant spatial frequencies are higher than 6 cpd whereas his sensitivity is greatly reduced for lower spatial frequencies. Similar results were found in another contrast sensitivity study that also determined the ability of subjects to detect and identify targets (23). The data shown in Figure 10 were obtained using two subjects having 20/50 and 20/30 Snellen acuity without their glasses and one subject having normal Snellen acuity, 20/20. The differences in Snellen acuity between these subjects agrees with the differences in contrast sensitivity for spatial frequencies smaller than 16 cpd: decreased Snellen acuity corresponds to decreased contrast sensitivity. However, note the large differences in contrast sensitivity between the subjects having 20/20 and 20/30 acuity from 6 to 16 cpd that are not predicted from their Snellen acuity. The question whether or not these differences in contrast sensitivity are functional is answered by their ability to detect and identify Snellen letters and aircraft silhouettes under low contrast conditions. In almost every case, the subject having 20/30 was significantly more sensitive than the subject having 20/20. The one notable exception is the letter identification task for the smallest letters where fundamental frequency was 12 cpd. The subject having 20/20 was more sensitive than the subject having 20/30. However, from the previous analysis, a letter having fundamental frequency of 12 cpd means that the relevant spatial frequencies for letter identification will be about 18-30 cpd. It would be expected that increased ability to identify Snellen letters would require increased contrast sensitivity of sine-wave gratings for 18-30 cpd. That result is quite evident from the data. The reversed performance for letter identification between those two subjects at the higher spatial frequencies is predicted from their contrast sensitivity functions and from their Snellen acuity. Therefore, contrast sensitivity to sine-wave gratings appear able to relate to certain aspects of target acquisition over the full range of target size.

These data have shown that significant differences can and do exist between individual contrast sensitivity that determine the amount of contrast necessary for an individual to detect and identify targets whose size varies over a large range. Although these data relate to limited scenarios in which targets are slowly moving or stationary and/or under conditions of ocular pursuit where the target remains somewhat localized on the retina, this approach may also be applicable to more dynamic conditions of target acquisition such as rotation and zoom where targets rapidly change position, direction, orientation, and size. However, current visual science suggests that static and dynamic targets are processed by somewhat independent visual mechanisms (e.g., 25). This means that tests of static visual acuity will not necessarily relate to dynamic visual acuity and that those kinds of functions will require separate tests. This is precisely what Ludvigh (26) found in early studies of dynamic visual acuity. Those studies showed quite large individual differences

in dynamic visual tasks that required the detection of Landolt targets presented at different velocities. Unfortunately, there has been little follow-on work in that area. However, we have begun using the preceding contrast sensitivity approach to determine individual ability to detect and identify simple and complex targets under dynamic conditions. Our pilot studies show significant individual differences within and between static and dynamic target conditions. This approach will be extended to other operationally relevant viewing conditions such as low luminance (night-time conditions) and peripheral viewing. The main point to be emphasized is that there cannot be any unitary measure of visual capability that will be relevant to all possible viewing conditions. Needed are tests of visual capability that relate to the different target and viewing conditions that will be encountered in the operational environment. The approach presented here using static targets represent a first step in that direction. More work will be needed to determine the relative importance of each of these kinds of tests for visual target acquisition.

It should be pointed out that the dichotomy between the physiological and cognitive aspects of target acquisition created in the introduction of this paper is not that clean cut. What part of individual differences used in detecting and identifying the targets shown in Fig 10 are due to physiological or cognitive factors such as threshold criterion or the particular selection of relevant target features needs to be determined. Pilot experiments in our lab using non-criterion free paradigms such as method of adjustment and a review of contrast sensitivity data using sine-wave gratings in criterion free signal-detection paradigms reveal that about a factor of 1.5 to 2 in contrast is needed to go from chance detection to almost certain detection (e.g. 24). It would seem, therefore, that factors other than criterion are required to explain differences in individual contrast sensitivity when they differ by more than a factor of 2. Although the relative importance of such factors as physiological sensitivity and criterion could be determined experimentally, the finding that the individual's contrast sensitivity to gratings relates to his ability to detect and identify complex targets suggests that these differences are functionally important regardless of the degree to which physiological and cognitive components each adds to the result.

These results have concentrated on the implications of individual visual capability at near threshold levels of contrast. Although those regions of contrast are important in many operational environments, a large amount of viewing also uses suprathreshold levels of contrast. There is evidence that individual differences exist in the suprathreshold contrast perception (27, 28). The degree of importance that these differences will play in the various aspects of target acquisition is not clear; however, it would seem that once target information is above threshold that sufficient contrast exists for any perceptual task. Although one individual may see that information at a higher contrast level than another individual, relatively small differences in visibility may not be significantly beneficial. Indeed, in certain cases it may be harmful. Consider, for example, the case where two individuals are viewing a video display on which relatively high contrast, high frequency noise and/or scan lines are visible. Since it is well known that high spatial frequencies mask low spatial frequencies (29), it would follow that the more visible the high frequency noise, the more masking or the less visible would be certain lower frequency targets. On the other hand, increased target contrast does mean increased dynamic range which could in other cases provide increased signal-to-noise conditions that relate to image quality. For example, increased suprathreshold contrast perception may provide an increase in the number of perceived grey-scale values which could increase the contrast discrimination of different target information. In any case, how individual differences in perceived suprathreshold contrast relate to visual target acquisition awaits further experimentation.

These differences in individual visual capability also have implications for pilot workload. Today's high technology aircraft coupled with more complex combat environments create high workload conditions. Many decisions critical to combat success demand complex tasks to be correctly performed in short time spans of several seconds. Any increase in time to perform those tasks is important. Since distance equals rate times time ( $d=rt$ ), increased target acquisition range and/or certainty of target acquisition will offer the pilot more time to perform other critical combat related tasks. Therefore, optimizing visual capability may in many instances reduce operator workload. Here too, further experimentation is needed to determine the relative importance of superior vision in complex environments. However, the data so far indicate that at least under some conditions, individual differences in contrast sensitivity could play a major role in certain cases of early target acquisition.

In summary, for vision limited tasks such as target acquisition in a high performance aircraft, the pilot should have maximum optical and physiological visual capability. Although more data is needed to determine population variances in contrast sensitivity and how those variances relate to complex target acquisition, given that all other relevant factors are equal, and whenever possible, it is suggested that observers with the highest contrast sensitivity be placed in the most vision intensive tasks. The placement of high sensitive individuals in positions requiring high visual capability may not guarantee their success under all conditions, however, it will at least optimize the probability of success under many conditions that require visual target acquisition.

#### CONCLUSIONS

This brief paper has presented data that show the limitations of present visual standards based on acuity measurements in being able to measure normal as well as abnormal visual function in a manner that relates to visual performance over a wide variety of

operational environments that effect contrast. A more powerful and parsimonious measure of visual capability - contrast sensitivity - was presented. Important differences between individual contrast sensitivity functions were shown to relate to one's ability to detect and identify letters and aircraft targets over a large range of target size and contrast under static viewing conditions. Present research is extending those results into dynamic viewing conditions. The collection of large population data of contrast sensitivity that is needed to determine the extent of normal variance has begun. Simulator studies that will lead to field trials that relate individual contrast sensitivity to various aspects of target acquisition are scheduled. Although we are still a long way from being able to establish new vision standards based on these emerging techniques, it is recommended that standardized testing equipment and procedures be developed to begin the collection of contrast sensitivity data in parallel with conventional vision tests. At a minimum, contrast sensitivity can be used to screen very high and very low sensitive individuals for further testing and/or observations. In addition to building up a data base, early exposure of the medical and operational communities to contrast sensitivity tests will sensitize individuals to limitations of acuity measures and encourage quicker acceptance of new visual standards based upon these techniques as they may develop. Especially important to the operational community is the fact that the contrast sensitivity results will continue to be related to task performance that in turn will encourage the medical and operational community to work more closely together in establishing and maintaining relevant visual standards. Hopefully, it will not be too long before those contrast sensitivity techniques can be used to create standards that have the potential to help optimize the capability of that most important component of visual target acquisition: the human observer.

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#### FOOTNOTE

Much of the data and discussion in this paper was presented at the Annual Scientific Meeting of the Aerospace Medical Association, Washington DC, 14-17 May 1979 (p. 81-82) and at an invited presentation, "Emerging Techniques for Assessing Vision" at the National Research Council Committee on Vision Annual Meeting, National Academy of Sciences, Washington DC, 15-17 April 1979.

## DISCUSSION

DR H M BORCHGREVINK (NO)

I would like to draw your attention to the correlation between hearing and what you have just pointed out for vision. Both are functions of pattern perception. As there is a clear-cut difference between a person's speech comprehension in silence and in noise, it seems relevant, in vision, to test not only the figure to background contrast necessary for object detection and identification but also to include visual pattern recognition in "visual noise".

AUTHOR

The correlation between vision and hearing has not gone unnoticed as you will find in my paper and the references it contains. Your point about the difference between perception with and without noise is an important one. However, the contrast sensitivity approach presented is dealing with the physiological sensitivity of the visual system to transmit visual data whether it is noise-free or not. The manipulation of that data, ie. separating figure from ground, is perhaps more relevant to how the individual attends to and uses the visual information in 'channels', narrow-band spatio-temporal filters that make up the overall visual filter used to separate the figure-ground information. The channels are briefly mentioned in my paper and in more detail in reference 12. Tests will be developed later for this type of visual capability.

DR G PERDRIEL (FR)

Sensitivity differential is an effective parameter in the measurement of central vision.

Nevertheless, I think that the estimation of angular vision acuity is more reliable in the assessment of aircrew since the use of contrast sensitivity requires the use of psycho-physiological faculties, which can vary from one examination to another.

AUTHOR

Visual acuity is ideal in refraction and the prescription of glasses, but contrast sensitivity has more relevance in the retinal-brain physiological system and the interpretation of the retinal image. You also referred to the day-to-day variation in results. We have completed longitudinal studies and have found subjects, repeatedly examined, maintain a certain average. Creating standards will take time, however, and at present we are collecting a data base.

## BIOFEEDBACK REHABILITATION OF AIRSICK AIRCREW

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## SUMMARY

The current USAF School of Aerospace Medicine treatment program for airsickness is reported in detail, describing treatment method and results. This program is based on biofeedback relaxation training and physiological monitoring in a motion-stimulus environment. Twenty aircrew, disabled by chronic, severe airsickness, were treated and followed. Two of this group were subsequently grounded for reasons unrelated to motion sickness, 2 were deleted from UPT due to continued motion sickness, 1 was disqualified from back-of-aircraft radio operator duties due to motion sickness, and 15 have been successfully returned to operational flying.

## INTRODUCTION

Airsickness continues to be a significant problem for student pilots and navigators, and for experienced aircrew changing aircraft or mission profiles. The current SAM Airsickness Treatment Program, based on physiological monitoring and biofeedback relaxation techniques, began in August 1979. Twenty aircrew, flying various aircraft, had completed the program by 15 Jun 80 and provide the data for this report.

Following treatment of this cohort of 20, 2 have been grounded for reasons unrelated to motion sickness, 2 were deleted from undergraduate pilot training (UPT) due to continued motion sickness, 1 was discontinued from back-of-aircraft radio operator duties due to continued motion sickness and 15 have been returned to operational flying. We shall take a closer look at this group later on.

Let us look at the patients, the criteria for selection, the method of treatment, the criteria for return to operational flying and the follow-up period.

## METHOD

All patients are active duty military aircrew, including 9 student pilots, 3 F-111 navigators, 1 C-130 loadmaster, 1 KC-135 refueling boom operator, 2 B-52 navigators, 1 F-4 navigator, 1 C-130 pilot, 1 C-130 navigator, and 1 RCB-5 radio operator. All were grounded for chronic disabling motion sickness and had previously been provided every standard USAF approach, including a series of trial flights with dexedrine/scopolamine or phenergan/ephedrine. All were reviewed by their squadron commanders and flight surgeons as highly motivated.

A patient typically enters the program on Wednesday, processing through a complete SAM medical evaluation. Intercurrent medical conditions related to motion sickness or potentially grounding of themselves (e.g., kidney stones) are ruled out, and the patient is cleared for treatment by Friday afternoon. He is then interviewed by a flight surgeon/psychiatrist. The patient's motivation to fly is once again assessed and personal factors possibly interfering with treatment are explored. During the years of our former airsickness treatment program (before biofeedback was employed) we had learned that patients' motivation to fly had not always been accurately assessed, or that the patient had never been given an opportunity to truthfully express negative feelings about flying, or that the aviator had not been able to honestly look at his feelings until he was away from home base. Following such an assessment and soul searching, the current treatment program and its rationale is explained in detail to the patient. It is important to note that aviators are highly intelligent, frequently have degrees in engineering, want to know about biofeedback learning loops and state-of-the-art physiological monitoring equipment, and do not appreciate a laying on of hands, black box approach. At the conclusion of this first interview the patient is instructed in biofeedback relaxation exercises and provided written instructions as well, then practices these exercises over the weekend and begins the treatment program on Monday. For those interested, I have brought several copies of our relaxation exercise instruction sheets. If there are not enough to go around, please sign the request roster and we'll send them to you. (Send written requests to Dr. Jones, USAFSAM/NGN, Brooks AFB, TX 78235.) I will demonstrate these exercises to illustrate their ease and simplicity.

The basic premise to our treatment program is that motion sickness is mediated by the autonomic nervous system and that learning voluntary control of the autonomic response to motion allows interruption of that response. The airsickness response typically consists of hypersalivation, pallor, cold sweating, warm flush, malaise, nausea and vomiting. It is the prodrome to vomiting, referred to as the passive phase, that is most disabling to our aircrew patients. It was our original speculation that interrupting the autonomic chain of events as early on as possible would abort or diminish an episode of airsickness.

The personnel we have used for this program are two flight surgeon psychiatrists, who share in the supervision and treatment of patients, and one biofeedback technician. All personnel are thoroughly trained and experienced with biofeedback equipment and relaxation techniques. Adequate training means a minimum of 16 hours of self-instrumentation and learning self-regulation of physiological processes. All this should be under the supervision of an experienced professional, experienced both in biofeedback techniques and the actual treatment of patients with psychophysiological disorders. Biofeedback treatment techniques can produce undesired reactions. Underlying suicidal depressions and borderline psychotic states can be precipitated in susceptible individuals; hence the need for careful psychiatric screening. Medication dosage levels often require adjustment during and after treatment (e.g., insulin requirements); this has not been a problem in our special population, but is important to note. However, aviators do employ over-the-counter antihistamines for upper respiratory infections and they must be warned of the potential increase in sedative effects of the medication.

The equipment consists of a motorized chair which rotates counterclockwise at speeds varying from 1 to 20 rpm and tilts right or left 40°. On a shelf, approximately 18" in front of the patient's face, are a bank of solid state electronic instruments measuring galvanic skin response (GSR), surface skin temperature and muscle electrical potentials. All instruments are provided with digital, meter, audio and light feedback. Our patients generally prefer to use digital information. The motorized chair is mounted with a slip ring facility allowing physiological data to be transmitted to a remote acquisition area and printed out every 5 seconds.

The first treatment session involves checking out the patient's relaxation techniques, including diaphragmatic breathing, progressive muscle relaxation, and mental imagery. Then the patient is introduced to the chair, familiarized with the equipment, and chair rotation is initiated. The patient's response to motion is observed by the patient as well as by treating personnel. Motion-sick-susceptible individuals typically respond with increased GSRs and lowered surface skin temperature, as well as increased muscle tonus. Peripheral vascular constriction, as in pallor or cold sweating, is recorded as drops in temperature from resting baseline level. General autonomic arousal resulting in sweat gland activity is recorded as increased levels of GSR. During the following 19 treatment sessions, which occur twice daily and last about 45 minutes, the patient receives increasing levels of motion stress as he successfully interrupts each motion sickness response. The patient also learns to recognize the earliest premonitory signs of impending motion sickness as he monitors his physiological status and can associate certain cues (e.g., muscle tension in the abdominal area), thereby providing a starting point for tuning down his autonomic arousal level. Our patients are brought to the brink of motion sickness several times in any one treatment session; their goal is to abort each episode as effectively and quickly as possible. By the final session the patients are aborting a motion sickness response within seconds under maximal stress.

Let us take a closer look at the treatment technique. Our patients are originally instructed in the basics of progressive muscle relaxation, mental imagery and yogic breathing as I have previously demonstrated and are detailed in the available handout. As treatment sessions progress patients individualize and abbreviate their relaxation routines. Typically, a patient will discover which group of muscles provide the greatest feeling of relaxation or the largest transfer to peripheral vascular dilatation and hand warming. For example, he may do only a shoulder shrug over 10 to 15 seconds. Another patient may discover muscle tension in his quadriceps as a consistent prodrome to passive motion sickness and will only contract and relax his quadriceps. As the patient's breathing technique improves, he may take only 1 to 3 diaphragmatic breaths and immediately swing into a mental image, bypassing muscle relaxation techniques. Patients must be introduced to the complete basic routine and then allowed to pursue their individual paths, provided they are gaining autonomic control. The observer, flight surgeon or technician, monitoring the patient's progress via careful observation of instruments and physical appearance, verbally reinforces successful control over autonomic response to motion and interrupts routines that are unsuccessful or partially successful. For example, one B-52 navigator would begin to gain autonomic control using a pastoral image (farm field, trees, leaves rustling in the wind), but would consistently lose control after 10 or 15 seconds. He was interrupted and it was discovered that this initially relaxing image would evoke personal memories of youth and blow his relaxation. A simpler, memory-free, mental device was suggested and was successful. The loss of control is early picked up by noting a sudden rise in the GSR after a consistent diminution and/or a reversal of a warming trend in surface skin temperature.

A mental device is a centuries-old technique for clearing the mind of intrusive thoughts and images. By persistent focus on an image (e.g., the black number 1 on a white background--our pilots prefer to use the ace of spades--or a flowing stream or waves rolling in on a beach), all other mental material is pushed out. This technique is similar to the nonsensical chant of a sanskrit word by practitioners of Transcendental Meditation as they achieve mental relaxation. Our aircrew will use flashes of an image developed during their treatment while actually flying operationally. They will not chant sanskrit or visualize the ace of spades for any length of time. As our patients get better and better at achieving reversals of their previously unpleasant response to motion stimuli, and as they practice and modify their relaxation routines at home, while driving, or behind their desk, their actual use of the technique while flying is semi-automatic and does not interfere with normal flying duties.

Following completion of the program at SAM, the patient is back in his aircraft within 1 to 3 days. Delays in return to flying diminish the chance for success and are avoided. A series of 5 trial flights of gradually increasing stress, reaching full operational profile, is required before a 6th, final check flight. Our patients call us after each flight and debrief, specifically discussing their physiological response. Suggestions are made by our staff regarding any problems which occur. If the 6th ride is reached and passed, the aviator is returned to flying status. Followup periods, as of 15 Jun 80, vary from 1 to 11 months. All 15 aviators successfully returned have passed their check rides and are successfully flying. In addition, 1 F-111 navigator, deleted for medical reasons unrelated to motion sickness, has been returned to flying status. Therefore, we now have returned 16 of 19 eligibles to status. There have been 3 failures due to continued motion sickness and 1 disqualification of a student pilot for mechanical flying deficiencies unrelated to motion sickness.

Let us briefly review the failures:

1. Student pilot, 65 flying hours post-treatment, received "goods" and "excellents" on all check rides; nonetheless experienced occasional persistent passive motion sickness. His instructor pilot felt that the patient would not be "safe" in solo formation flying.
2. Student pilot, 2 flying hours post-treatment, experienced persistent motion sickness and self-eliminated, honestly stating his desire to stop flying and pursue another occupation.
3. KC-135 radio operator, whose first mission after completion of the treatment program was a 7-hour marathon of turbulence and pattern work and active airsickness for the patient, who said "enough" and self-eliminated from flying duties.

#### CONCLUSIONS

In closing, we note an 84% return rate of previously disabled aircrew. Prior to the use of biofeedback, the SAM airsickness treatment program enjoyed a return rate of 45 to 50%. The earlier program employed adaptation and psychological desensitization techniques. It is impossible to say how biofeedback works, but it appears to be reasonable to say that it can work. With careful selection, including a careful and realistic assessment of motivation, a high return rate of motion-sickness-disabled aircrew can be achieved.



## DISCUSSION

DR K MYHRE (NO)

It has been reported that in some cases, where migraine has been successfully treated by biofeedback methods, other symptoms such as peptic ulcer have developed. Can you comment on this?

AUTHOR

Szajnberg & Diamond in Headache 20(1): 29-31 Jan 1980 reported symptom substitution in 8 of 12 patients treated with EMG biofeedback in 1973/74. Three patients reported a variety of symptoms (joint swelling, abdominal pain etc.), two reported psychological symptoms, and two reported a change in their personality. Ten of the 12 had 'a significant neurotic depressive component' pre- and post-treatment, and most patients felt that things happened to them outside their control. The authors postulate that removal of migraine is a stress that upsets homeostasis and may result in a new adaptation which may include new diseases. I know of no studies similar to this one. If their hypothesis is true, however, it would be true regardless of the means by which the headaches were controlled. By analogy, curing peptic ulcer might lead to a similar outcome.

DR K E MONEY (CA)

Since the essence of motion sickness, nausea and vomiting, does not involve the autonomic nervous system in any important way, if at all, could you suggest an alternative theory for the very impressive results you are achieving in practice?

AUTHOR

Although denervated stomachs can vomit, it may be that there is an autonomic input into motion sickness in the intact individual. Certainly the prodrome symptoms of vasoconstriction and sweating which we interrupt through biofeedback techniques are mediated by the autonomic nervous system. Our techniques also allay anxiety, which in itself may cause nausea and vomiting (as in the pilot who vomits before he gets into the aircraft), and this anxiolytic action undoubtedly contributes to our results, as does the subjective influence of the therapist. These anxiety-reducing effects are most likely mediated through the limbic system and may, through some sort of gating effect, serve to diminish the somatic response to the vestibular input. In lay terms, they learn to control it, and then to ignore it, and so it doesn't bother them.

PSYCHOLOGICAL THERAPY AND PREVENTION OF STRESSREACTIONS  
IN GERMAN MILITARY PILOTS <sup>1)</sup>

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Summary

The disturbances of 44 aviators of the German Military will be described and documented. The people concerned were pilots and navigators involved in a psychological intervention and counselling program over a period of 1973 - 79. The aim was flying rehabilitation.

The somatic, psychic, and social symptoms will be analyzed under the heading of modern stress conceptions.

We will propose psychological prevention methods in order to reach a better stress tolerance. And also with high probability, these procedures will modify the operational behavior patterns under extreme missions conditions. They will help to prevent disturbances of health, and minimize flight safety risks.

---

1)

This paper is dedicated to the senior psychologist and Head of Department VI, Aviation Psychology, Institute of Aviation Medicine, GAF, RDir. Dr. K. Gerbert, Col. (Reserve), Dipl. Psych., Clinical Psychologist, who is the initiator of psychological training and therapy programs with aircrew in the German Military.

Sample

44 persons of the Flying Personnel of the German Military will be reported on. They took part in a psychological rehabilitation program between 1973 and 1979. After a time lapse of 2 years each person had a review.

The number of persons is only 1 % of the total Flying Personnel, but it is a good representation of the people that we see in the Department of Aviation Psychology at the Institute of Aviation Medicine of the German Air Force. The only people excluded are the ones with special aptitude problems.

This sample consists of 2 groups:

Table 1

A COUNSELLING		B THERAPY	
persons	20		24
pilots	17		20
navigators	3		4
Jet *	12		12
Prop **	8		12
flight time/hrs.			
average	605		1047
range	1 - 2500		6 - 4250
amount of counselling/hrs		amount of therapy/hrs	
max	5	average	26 hrs
		range	6 - 50 hrs

\* Jet: G-91, F-104, F-4F, RF-4E

\*\* Prop: Piper L-18, Pi-149D, C-160 Transall, HFB-320;  
Alouette II, UH-1D, Bell Jet-Ranger

The amount of flying hours for group B are nearly doubled that of Group A. This leads to the conclusion that, the amount of flying hours could be in relation to severity of problems.

Complaints

As you can see in Table 2 there are 4 definite categories of complaints. In these categories we have found 2 main complaints. One is a general fear of flying (10 people), and airsickness (7 people). We want to point out, that these are specific job related symptoms.

Table 2

<u>PSYCHIC COMPLAINTS</u>	No. of persons
general fear of flying	10
phobias	3
depressive reactions	3
anxiety neuroses	1
psychasthenia	2
mental overload	1
loss of flying motivation	1
	<u>21</u>
<u>PSYCHOSOMATIC COMPLAINTS</u>	
airsickness	7
gastrointestinal system	3
circulatory system	1
respiratory system	3
musculatory system	1
	<u>15</u>
<u>PSYCHOSOCIAL CONFLICTS</u>	
family/spouse	5
<u>DRUG ABUSE</u>	
alcohol	3

First we will see how the complaints are distributed over the 2 groups of aviators, jet and prop (including helicopters). As you can see in Table 3 there are more psychic complaints from jet personnel, and more psychosomatic complaints from prop personnel.

Table 3

Complaints	Jet		Prop	
Psychic complaints	14	58 %	7	35 %
Psychosomatic complaints	6	25 %	9	45 %
Psychosocial conflicts	4	17 %	1	5 %
Drug abuse	-		3	15 %

Now for a brief look at general fear of flying:

Table 4

<u>General Fear of Flying</u>		
persons		10
	pilots	9
	navigators	1
flight time/hrs		
	average	28,5
	range	250 - 2650
incidents		2 (1 caused by human factor)
accidents		4 (2 caused by human factor)
rejections: 1 person 2 x)		
successful flying rehabilitation		6
eliminated		4

We must point out that every person involved in an accident, or incident in our sample, developed a fear of flying; however, this is not the only factor involved. 2 of these specific persons were exceptionally good fighter pilots. They succeeded in the rehabilitation program, but gave up flying approximately one year later. We will come back to these two later.

Now a brief look at airsickness:

With airsickness symptoms the relationship between pilot and navigator is reversed. This is obvious because of the navigator receiving more vestibular stimulation. As you can see from Table 5, they have a lower number of flying hours.

Table 5

<u>Airsickness</u>		
Persons		7
	pilots	3
	navigators	4
flight time/hrs		
	average	28,5
	range	4 - 70
successful flying rehabilitation		4
unsuccessful		3

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ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT--ETC F/G 6/14  
THE EFFECT OF LONG-TERM THERAPEUTICS, PROPHYLAXIS AND SCREENING--ETC (111)  
MAR 81 C E SIMPSON

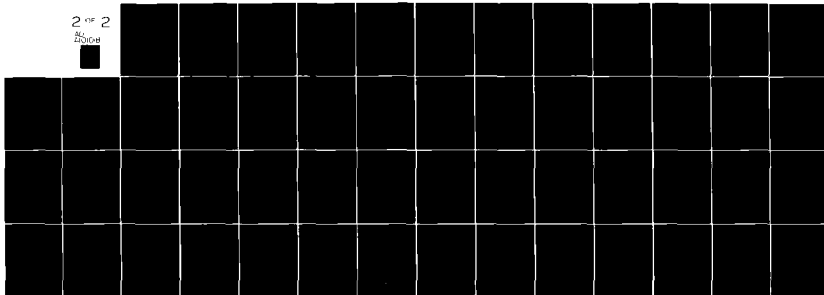
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Airsickness seems to be a typical complaint from the early stages of flying. These symptoms arose despite being tested in a certain way. Many psychic determinants belong to this complaint. We interpret it in relation to the sensory dissonance theory (HOFFELT 1976 et al.). More than half recontinued flying after psychological rehabilitation.

#### Intervention techniques

In all cases there was a psychological exam before beginning in the program.

The counselling program consisted of 2 phases:

- a) information on exam results and their consequences
- b) supervision in practical training:
  - physical fitness (emphasis circulatory system)
  - relaxation training
  - non-directive counselling

However, the therapy program was more extensive (see Table 6).

Table 6

Therapy Program
Pre Phase 3 - 4 weeks
Main Phase 4 - 8 weeks
Transition Phase 3 - 4 weeks

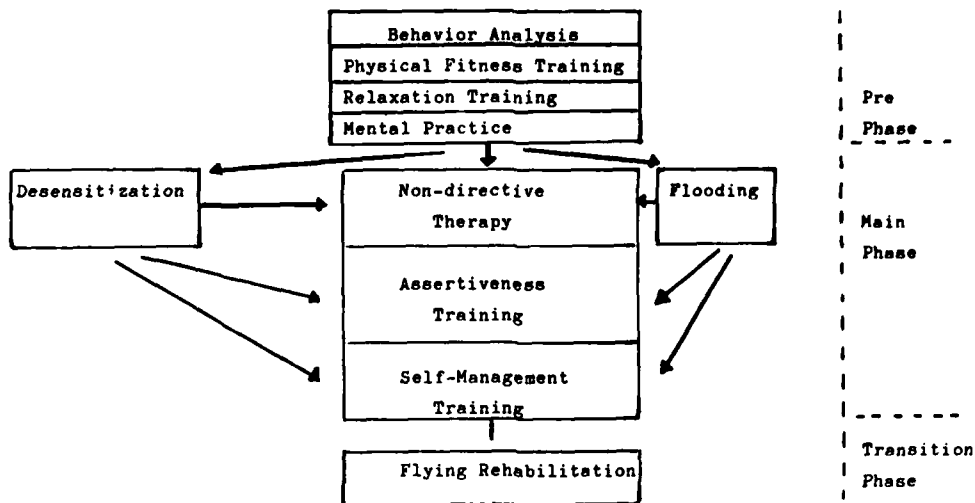
Prephase is intended to stabilize the circulatory system, to increase stress tolerance, and teach relaxation training. The latter is a combination of progressive relaxation technique (JACOBSON) and autogenic training (SCHULTZ). A mental practice also belongs to their pre-phase. It is a very effective method in high achievement sports. In therapy programs we use it as in systematic anticipation of stressful situations. It is an important part of desensitization, assertiveness and self-management techniques (KEMMLER 1979).

The pre phase also includes a behavior analysis (see Table 7).

This should offer the genesis of the disturbances, the situational context, and should lead to procedures of intervention (KANFER & PHILLIPS 1975).

As you can see in Table 7 there are a variety of therapy techniques, based on learning theory.

Table 7



After the main phase there came the transition, with support of simulators. Especially for airsickness, we used a Spatial Disorientation Simulator, with which we are able to produce different forms of acceleration, and vestibular stimulation. The flying rehabilitation would be discussed with the instructor pilot. In most cases there are about 10 missions with increasing difficulty levels (GERBERT & OBERHOLZ at AGARD 1974). When the program was successfully completed clearance was received immediately.

### Results

The effect of the psychological intervention, counselling, and therapy, is shown in Table 8.

Table 8

Effect of Intervention					
A Counselling			B Therapy		
successful	14	70 %	15	62,5 %	
unsuccessful	6	30 %	9	37,5 %	

It is necessary to point out that successful counselling and therapy does not automatically mean successful flying rehabilitation. For this reason, we let 2 years pass before reviewing the aviators. Their flying status is seen in Table 9.

Table 9

Flying Rehabilitation					
A Counselling			B Therapy		
successful	14	70 %	14*	58 %	
unsuccessful	6	30 %	10**	42 %	

\*) 12 persons continued flying  
2 persons were down-graded



•• 8 persons were eliminated  
2 persons declined to fly

In the persons who declined to resume flying, we noticed a heavy loss of flying motivation and a change in attitude towards aviation. This is obviously not the intended effect!

Now we come back to the 2 pilots mentioned earlier. They succeeded in psychological therapy and flying rehabilitation, but discontinued their flying career after approximately one year. Fear problems arose for the one, and the other could not cope with the pressure he received from fellow pilots. There are many prejudices about mental illness and therapy and this was not recognized during the therapy program. There should be more information attained on this. Some years past there was the same problem in high achievement sports. Now, it is a normal procedure for sportsmen to receive psychological support.

It is interesting to note that, this problem exists mainly in jet wings. You can also see in Table 10 that flying rehabilitation in jet aviators is lower than in prop aviators. O'CONNOR & LISTER found the same (AGARD 1974).

Table 10

Flying Rehabilitation of Therapy Group (B)			
Jet		Prop	
successful	5* 42 %	9	75 %
unsuccessful	7** 58 %	3	25 %

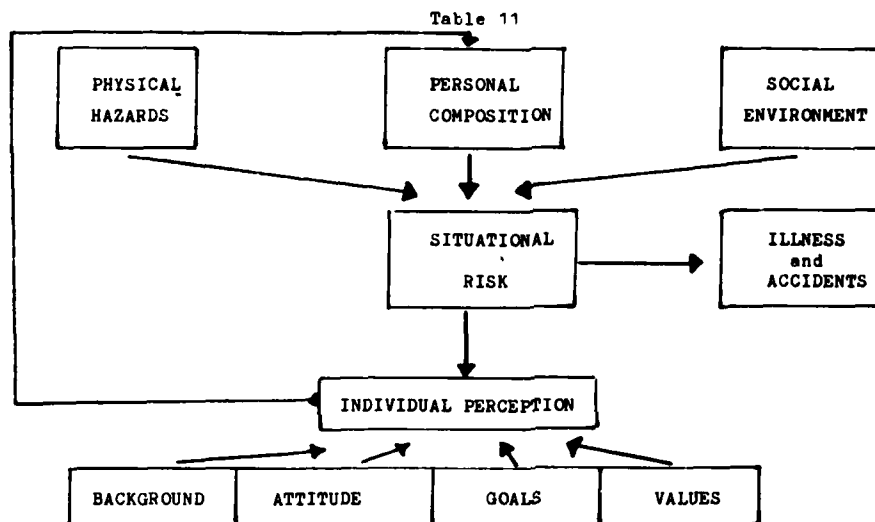
- \* 2 persons were down-graded
- 2 persons declined to fly
- 2 persons flew for 1 year and gave up

#### Etiology of Disturbances

For analyzing the disturbances we use the concept of man/machine system. The examples we will use will show the connection between the individual and environmental conditions; specifically the working conditions, social structure and situational conditions. Not only do we use the frame of reference of man/machine system to analyze the relationships of complaints and individual's biography, but the multidimensional causation and reinforcements. These complaints are the result of specific learning processes and experience. In most cases, the individual's socialization and learning history are the basis for the development of malfunctions. The trigger and reinforcers are found in relatively short dynamic feedback processes. There is a strong tendency to generalize, due to the high risk factor and to anticipation. The feeling of psycho-physiological arousal and psychological threat are the deceptive vehicles in the development of malfunctions. One dramatic situation, (eg. ejection) or many unrelated high tension situations lead to a typical stress reaction for each individual. Often they are reinforced through psychosocial problems or poor physical condition. The aviators do not realize these connections. They only realize, for example, a sense of helplessness; aggression or feeling poorly, as we say a decline in self-control. This leads to anticipation, aversion, and avoidance behavior. The situational items first are unconditional stimuli. They become reinforcers for the different stress reactions. It has been noticed that the cognitive and emotional evaluation of the anticipation of a stressful situation often leads to a stronger strain reaction than

the real situation produces. Aviators feel unable to cope with situations but don't realize that it is in actuality, a decline in self-control. They have reported in the following way: "I can handle the aircraft in every situation, for this there is a procedure. But I can't help it because of my symptoms. I have no control over my body."

Most of the aviators dissimulate in the early stages. But they do realize that there is a decrease in their abilities to solve problems, and analyze and process information. They recognize a disorganisation in planning and action. They don't perceive all information due to lack of concentration. They use their concentration for self-defense rather than business at hand. At this moment there exists a high situational risk (see Table 11). One of the most interesting processes is the feedback of individual perception and personal composition.



(PUGH, W.M., & GUNDERSON, E.K. 1979)

This is the moment that they begin to speak about their complaints. Sometimes, it seems to us, it will be too late.

When pilots talk about their complaints, it isn't positive that they would be understood or receive the proper help. Often flight surgeons haven't sufficient psychological training.

For 2 years we have been engaged in analysis of human factor accidents. The percentage of those accidents, in every form of aviation is very high. We found that the situational conditions are similar to those, in which somatic or psychic symptoms arose. An individual situation risk could be defined. It seems to be an indicator for all factors; dependant and independant of the situation. We were only able to make a limited prognosis. We had doubts about the results of NEUMANN's prognoses of accident-prone pilots. He works on the basis of a projective perception test (Defense Mechanism Test).

### Conclusions

We analyzed the disturbances of 44 aviators. We saw the symptoms as specific reactions to various stress conditions within the man/machine system. They seemed to follow situational determinants. We would like to propose the following procedures for preventing disturbances and malfunctions:

1. To establish psychological techniques for aircrew selection which measure learning processes under stress conditions.
2. To create a better training program, specifically in the area of increasing stress tolerance.
3. The most effective would be:  
The development of a preventive program.  
This would produce, not only better fitness, but also flight safety.  
How this program might look is:  
Find all central positions in the man/machine system. These are
  - aviators (and perhaps their relatives)
  - ops and duty officers (in the squadrons)
  - instructor pilots/navigators (rio, wso)
  - flight surgeons
  - flight safety officers

These people must all be uniformly informed about the development of malfunctions. They must be made aware of them. The next phase should be a special education program. This should lead to a higher level of competence in the relationship between these people. Some training in accident analysis, prevention, psychological ergonomics, and clinical psychology is preferred.

At the Institute of Aviation Medicine in the German Air Force we have begun the first steps in this direction. We organized seminars in psychological topics (eg. malfunctions in man/machine systems and exploration techniques with video feedback training). The reactions we received from the participants gave support to our ideas. Extra finances are not necessary for this program, only cooperation and organization.

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## DISCUSSION

MR R E F LEWIS (CA)

From your experience, once a member of aircrew has been involved in a significant aircraft accident do you think that, thereafter, he will retain a fear of flying to some degree?

AUTHOR

If he had learned to cope with the symptoms related to a fear of flying I think he would be able to remain in flying. In our experience, half of the aircrew involved in accidents or incidents returned to flying.

DR K E MONEY (CA)

Would you say that you are confident that the 4 out of 7 cases of motion sickness who returned to flying did so because of your intervention?

AUTHOR

I am sure that they are retained in flying because of the training we gave them. We use a technique similar to Dr Jones to provide desensitisation.

DR D R JONES (US)

We see quite a few people who have a fear of flying and many more with psychosomatic symptoms clearly related to flying. Almost all are not interested in therapy for their symptoms. The exceptions are those with a true flight phobia which they want to get rid of, and for them desensitisation works well.

How do you get your subjects who have lost their motivation to remain in therapy for so long?

AUTHOR

It does not work in every case. We do not call it therapy, but a training programme. Nor do we call this condition fear. We remove them from their squadrons for treatment.

# DETECTION OF DIAZEPAM AND DETERMINATION OF TIME OF INGESTION IN AIR ACCIDENT/INCIDENT INVESTIGATION

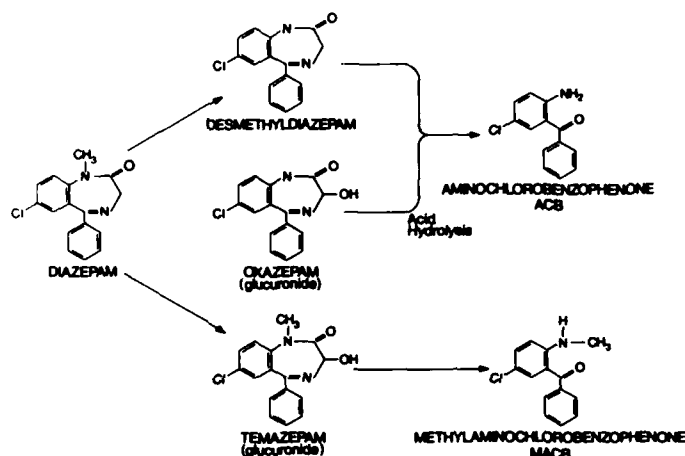
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Downsview, Ontario, Canada

## INTRODUCTION

Toxicological analyses are performed in our laboratory to assist in the investigation of military air accidents and incidents in Canada. We became aware several years ago that the screening procedure in use for tranquilizers of the benzodiazepine class, of which diazepam is a most common example, was extremely sensitive. In some cases, metabolites could be detected in the urine up to four weeks or more after a single therapeutic dose. In any interpretation of positive drug findings, therefore, we felt it important to be able to differentiate recent consumption, that is one to two days, from a later post-consumption period.

The major metabolic transformations of diazepam in man are shown in Fig. 1.

Fig. 1. Metabolic transformations of diazepam and acid hydrolysis products



Diazepam is virtually completely metabolized with less than 0.05% excreted unchanged in the urine (1, 2). Desmethyldiazepam is the major metabolite measurable in blood (2), while the glucuronide conjugate of oxazepam is the major detectable metabolite found in urine (3). On acid hydrolysis these benzodiazepines are converted to their corresponding benzophenones (Fig. 1) and this forms the basis of the screening procedure (4). The benzophenones are then separated by thin layer chromatography (TLC). The aminochlorobenzophenone (ACB) may be visualized after diazotization with the Bratton-Marshall reagents (5). Methylaminochlorobenzophenone (MACB) does not possess a primary amino group and therefore does not react to form a diazochromophore. If present in sufficiently high concentrations, however, as in the urine of a chronic user it may be seen as a faint yellow spot prior to diazotization. The appearance of MACB in some instances after recent dosing indicated that temazepam may be a significant metabolite in the early phases of metabolism. This present study was designed to examine the temporal excretion patterns of unchanged diazepam metabolites and to determine if there was a relationship between metabolite ratios and the time of ingestion. A clinical study was carried out using gas chromatography-mass spectrometry (GC/MS) to verify the presence of and to quantitate diazepam metabolites in the urine of human subjects after a single 10 mg dose.

## MATERIALS

Diazepam tablets (5 mg: Vivol B.P.) were obtained from F.W. Horner Ltd., Montreal. Pure standards of diazepam, desmethyldiazepam, 3-hydroxydiazepam (temazepam) and 2-methylamino-5-chloro-benzophenone (MACB) were purchased from Hoffman-LaRoche Inc., Nutley, N.J., oxazepam from Wyeth Laboratories, Toronto, Ont., and 2-amino-5-chlorobenzophenone (ACB) from Aldrich Chemical Co., Milwaukee, Wis.  $\beta$ -glucuronidase was obtained from Sigma Chemical Co., St. Louis, Miss. Derivatizing agent BSTFA, and silylation-grade pyridine were purchased from Chromatographic Specialties, Brockville Ont.

All glassware used in sample storage and preparation was silylated (6) to reduce adsorptive losses of metabolites during processing.

## CLINICAL PROTOCOL

Eight male subjects from 23 to 48 years of age and who had not taken diazepam for at least 8 weeks each received a 10 mg dose at 0900 hours on day 1. Urine samples were taken every 3 hours for 12 hours and thereafter every 12 hours for the first week, followed by 24 hour and finally 48 hour intervals for a four week period. An additional four male subjects each received a 5 mg dose and samples were collected for the first week. Samples were frozen at  $-20^{\circ}\text{C}$  in silylated glassware until analyzed. Creatinine levels were measured (7) on all samples and drug concentrations were expressed on this

basis to reduce errors due to volume fluctuation.

#### SAMPLE PREPARATION

Three ml urine samples were hydrolyzed with  $\beta$ -glucuronidase according to the method of de Silva and Puglisi (8). This procedure frees the bound hydroxylated metabolites from their water soluble complexes and enables extraction of total metabolites. The subsequent organic extraction and clean-up procedures were carried out using the method developed by Zingales (1). The trimethylsilyl (TMS) derivative of temazepam was formed by adding 50  $\mu$ l each of BSTFA and pyridine and heating the sample residue in a reacti-vial at 50°C for 20 min. The excess BSTFA and pyridine were removed using a stream of nitrogen.

Efficiency of extraction and overall recoveries of the metabolites were monitored either by carrying blank urines spiked with known amounts of diazepam and its metabolites through the entire procedure to obtain calibration graphs, or by adding diazepam to samples and quantitating using measured relative response factors.

In a number of cases, urine samples were analyzed for ACB and MACB after acid hydrolysis and TLC to separate the benzophenones and remove urinary contaminants. The ACB and MACB were subsequently eluted from TLC plate scrapings with methanol.

#### GAS CHROMATOGRAPHY - MASS SPECTROMETRY (GC/MS)

A Finnigan 4000 GC/MS operated in the electron impact (EI) mode with an INCOS data analysis system was used to obtain mass spectra. The analytical column was a 1.8 m by 2 mm i.d. glass or nickel column packed with 3% OV-17 on Chromosorb W-HP (80/100) mesh). Operating conditions were: injector temperature, 250°C; oven temperature, 240°C isothermal; helium carrier gas flow rate, 25 ml per min; transfer line and source temperatures, 270°C; electron energy 45 eV; emission current, 0.3 mA; accelerating voltage, 1800V. Multiple ion detection (MID) employing at least two ions per compound was used to verify the presence of and to quantitate each metabolite. Ions chosen for MID were usually the base peak and one or two other major peaks which showed minimum background contamination from endogenous urinary constituents present in the final extracts.

Dried residues or derivatized extracts were dissolved in methanol and a volume equivalent to 0.6 ml urine was injected onto the GC column.

#### RESULTS AND DISCUSSION

##### Gas chromatography - mass spectrometry

Fig. 2 shows the same mass spectra obtained from diazepam, desmethyldiazepam, oxazepam and the monotrimethylsilylated derivative of temazepam.

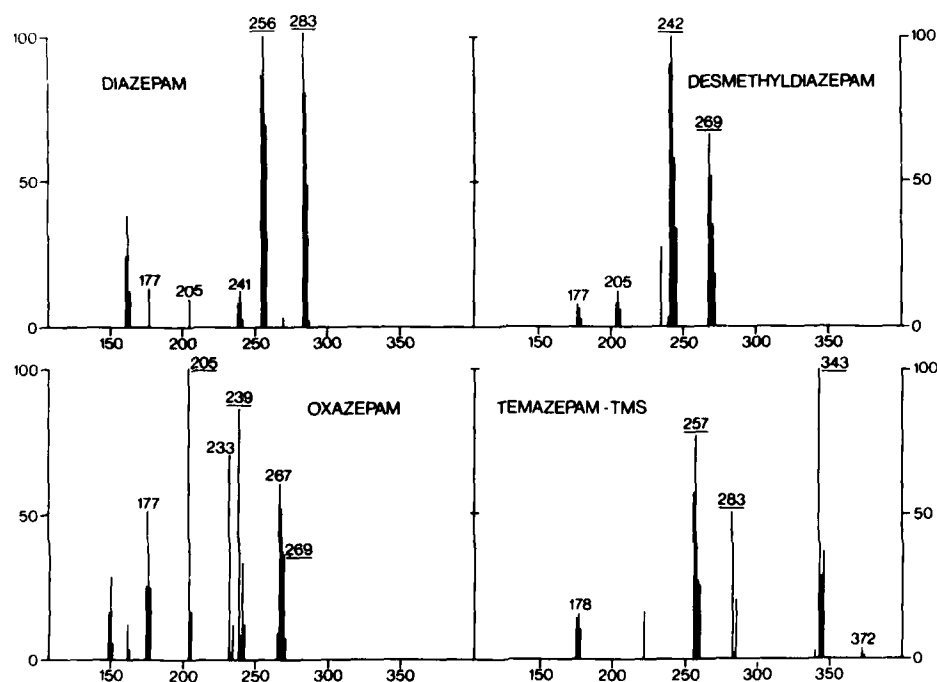


Fig. 2. Electron impact mass spectra of diazepam, desmethyldiazepam, oxazepam, and the monoTMS derivative of temazepam.

The masses underlined in Fig. 2 are those chosen for compound identification and quantitation. Under the analytical conditions used in this study, oxazepam was quantitatively converted to the quinazoline carboxaldehyde form (9) with a m.w. of 268 as no peak corresponding to unchanged oxazepam, m.w. 286, was seen in the total chromatographic screen of either the pure standard or urinary extracts. Oxazepam also appeared to resist silylation by BSTFA and the only peak observed post-TMS treatment was the carboxaldehyde. On the other hand, temazepam was completely silylated to the mono-TMS derivative under the same conditions. The presence of the methyl group on the N-1 appears to stabilize the molecule against thermolytic degradation and permits silylation of the C-3 hydroxyl group.

The silylated temazepam showed a significant increase in sensitivity, more than 100-fold, over the underivatized metabolite, and eluted as a sharp peak at half its former retention time. Fig. 3 illustrates a typical chromatographic separation of the three metabolites extracted from a drug-free urine sample spiked with 50 ng of each compound.

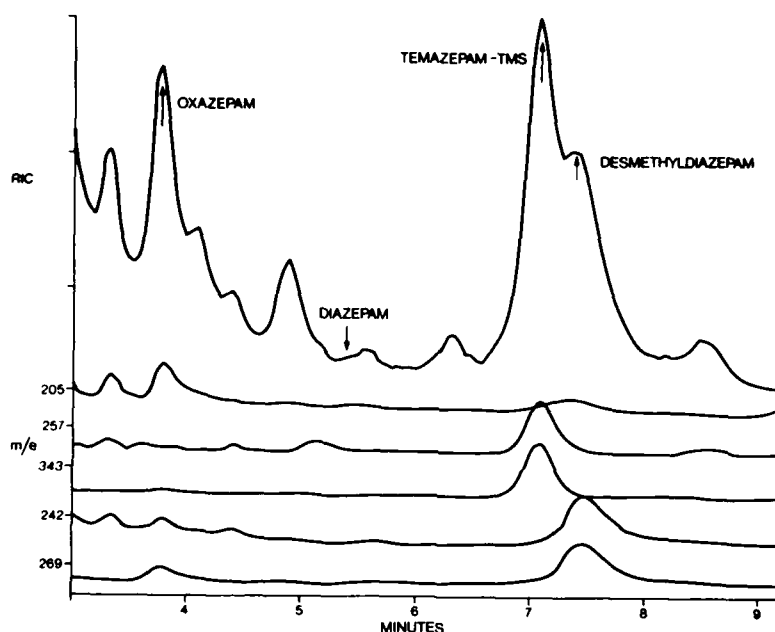


Fig. 3. Reconstructed gas chromatographic profile of the extract from a blank urine spiked with 50 ng oxazepam, desmethyldiazepam and temazepam. Single ion current profiles of masses selected for quantitation of the metabolites are shown below. For GC/MS conditions see text.

While the temazepam and desmethyldiazepam were not completely separated in the total ion current (upper tracing), the use of individual ions specific to each component (lower tracings) eliminated such interference and enabled quantification of one or more ions.

The overall recoveries of metabolites when added to urine as reference standards over a range of concentration from 10 ng to 200 ng per ml were 75 to 78% (coefficient of variation, 8.5%). Recovery of diazepam over the same range was 70% with a c.v. of 8.5%. Limits of detection were of the order of 0.4-0.7 ng per ml urine.

Mean levels of the three metabolites found in the urine of the eight subjects who received the 10 mg dose are shown in Fig. 4. Desmethyldiazepam concentration peaked 9-12 hr after ingestion, temazepam at 12-24 hr, and oxazepam levels rose more slowly, reaching maximum values between 1 and 3 days in all subjects. From day 2 (48 hr post ingestion) oxazepam was the major metabolite and its rate of elimination or excretion via the urine declined more slowly than the other metabolites.

The broken lines indicate that subsequent points on the graph are biased toward high values. This bias is the result of the decreasing sample size as various metabolite levels fell below concentrations which could be accurately quantified. Wide variations in metabolite levels among the test group individuals were seen as is indicated in Fig. 4 by the standard deviation. In most cases the distribu-



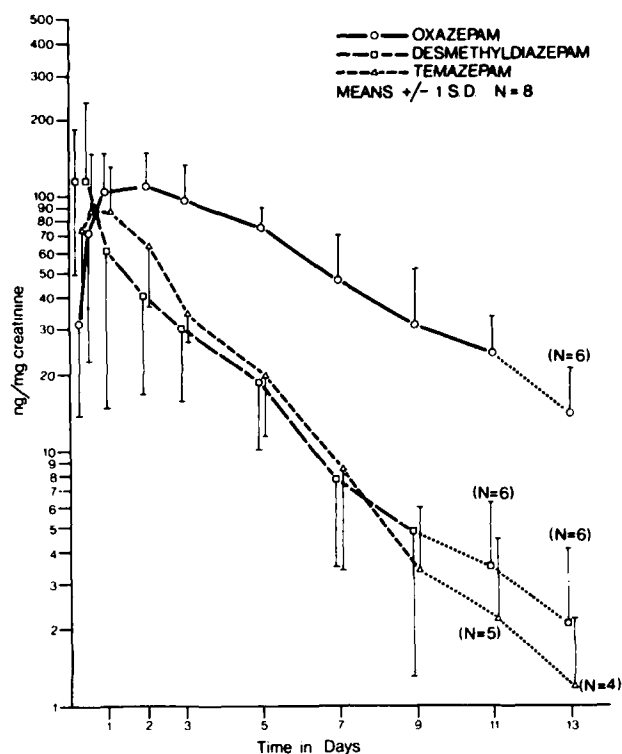


Fig. 4. Levels of diazepam metabolites in urine after a single 10 mg dose. Means  $\pm$  1SD.

tion of measured values tended to be bimodal or platykurtic rather than normally distributed about a mean. Such patterns in distribution might well be expected as a natural consequence of differing metabolite rates and therefore rates of elimination of the drug which have been observed between individuals (2). The actual ranges of values found for oxazepam, desmethyldiazepam, and temazepam in this study are presented separately in Figs. 8, 9, and 10 respectively at the end of the text.

Ratios of oxazepam: desmethyldiazepam (ox:des) and oxazepam:temazepam (ox:tem) were calculated for each subject and mean and ranges of these ratios for the first week are shown below in Figs 5 and 6.

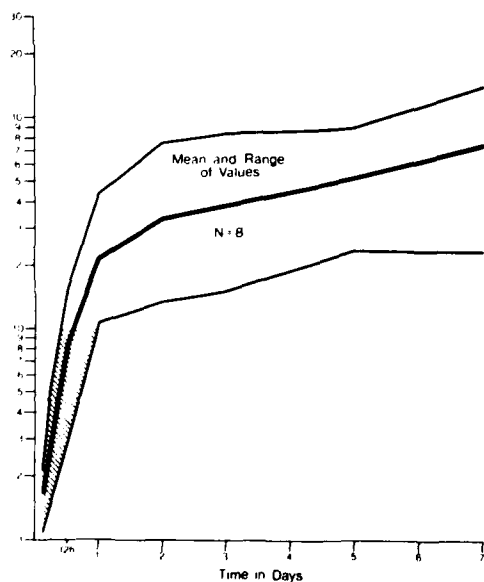


Fig. 5. Ratios of oxazepam:desmethyldiazepam. Mean and range for eight subjects.

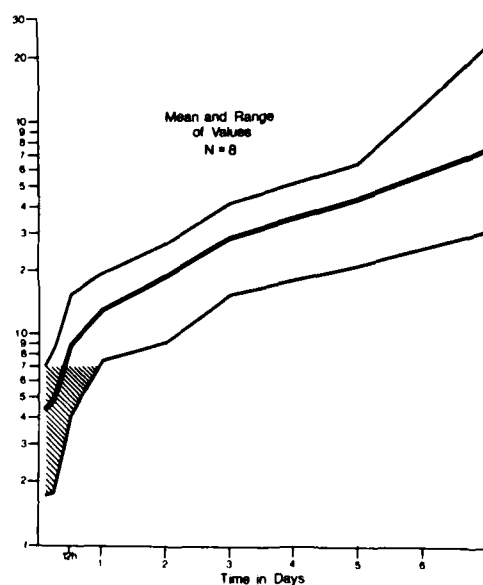


Fig. 6. Ratios of oxazepam:temazepam. Mean and range for eight subjects.

All ratios prior to 9 hrs were less than 1. However, such values could occur for up to 24 hrs in the case of oxides and for 48 hrs in the case of ox:tem. A value of 1 or less for oxides coupled with a corresponding ox:tem ratio of 0.7 or less would indicate ingestion within the previous 24 hrs. This combination was seen in 75% (24/32) of samples collected during the first 12 hours, and, in total, over 90% (10/12) had at least one ratio below these particular values during this time period.

Beyond one day, all values for oxides were  $>1.0$  and all ox:tem ratios were  $>0.7$ . Both ratios continued to rise although at much slower rates than seen during the first day. As a result, higher ratios cover very broad ranges in time and by themselves could not be expected to give rise to narrow time limits. However, the use of these ratios in conjunction with actual metabolite levels should provide the best indication of the accuracy attainable. To assess the usefulness of our control data results obtained from four subjects, each of whom received a 5 mg dose, were treated as unknowns with respect to both dosage level and time of ingestion. The metabolite concentrations and calculated ratios were compared to the data in Figs. 5, 6, 8, 9 and 10 to estimate both dosage and ingestion time. The results are given in Table 1.

Table 1: Estimation of dose and time since ingestion following administration of 5 mg Diazepam

Levels of metabolites in urine			Actual time since ingestion	Estimated dosage	Estimated time since ingestion
Ox	Des	Tem			
-ng/mg creatinine-					
8.3	9.2	15.2	6 hr	2 mg	9 hr-18 hr
12.8	48.3	14.1	"	5 mg	6 hr-9 hr
21.3	22.8	45.7	"	5 mg	9 hr-18 hr
40.2	27.5	41.4	"	5 mg	12 hr-2d
18.3	14.2	15.1	12 hr	2 mg	12 hr-2 d
22.3	31.6	61.4	"	5 mg	9 hr-12 hr
25.2	21.4	34.4	"	5 mg	12 hr-1d
121.0	101.7	78.7	"	10 mg	12 hr-1.5d
27.8	8.2	16.9	1 d	2 mg	1d-2.5d
28.4	11.3	18.8	"	5 mg	1d-1.5d
50.9	11.0	22.7	"	[10 mg or 5 mg]	4d-5.5d 1.5d-3d
108.6	23.1	49.3	"	10 mg	1.5d-3d
22.3	2.7	19.0	3 d	*	
38.1	14.2	17.6	"	5 mg	2d-5d
40.2	13.6	24.7	"	5 mg	1d-3d
54.9	17.8	13.5	"	[10 mg or 5 mg]	4.5d-6.5d 3d-4d
7.2	2.0	3.1	5d	2 mg	5d-6d
23.2	1.8	5.8	"	5 mg	6.5d-8d
26.0	5.8	13.2	"	5 mg	4d-5d
94.3	17.7	23.1	"	10 mg	3.5d-6d

\*No estimate possible: mutually exclusive values

The last two columns of Table 1, of estimated dosage and time, are predicted on the basis of metabolite levels detected. In two instances the values observed were compatible with more than one dosage level. In a third example, (\*), no estimation was possible because mutually exclusive results were obtained for ingestion times when ratios were compared to the control group data. The use of actual metabolite concentrations in conjunction with their ratios enabled not only an estimate of probable dosage received but usually resulted in an estimated range of time since ingestion which was shorter than the time span estimates based on ratios alone.

Values in Table 2 are taken from three cases of positive benzodiazepine findings in air incidents occurring prior to 1980. In their investigation, quantitative analyses were carried out on the acid hydrolysis products, ACR and MACB.

Table 2: Diazepam metabolite concentrations in urine of aircrew positive for a benzodiazepine drug.

	ACR	MACB	ACB:MACB
	-ng/mg-		
Case 1	11.0	0.9	12
Case 2	6.4	0.3	21
Case 3	29.0	2.9	10

The ACR:MACB ratio is equivalent to [ox plus des]:tem. The results from these three accident investigations are shown in Fig. 7 which is a plot of the additive metabolite ratio. In all three cases the indicated time of ingestion was more than 5 days prior to sampling time and the low metabolite levels would lend support to this estimation.

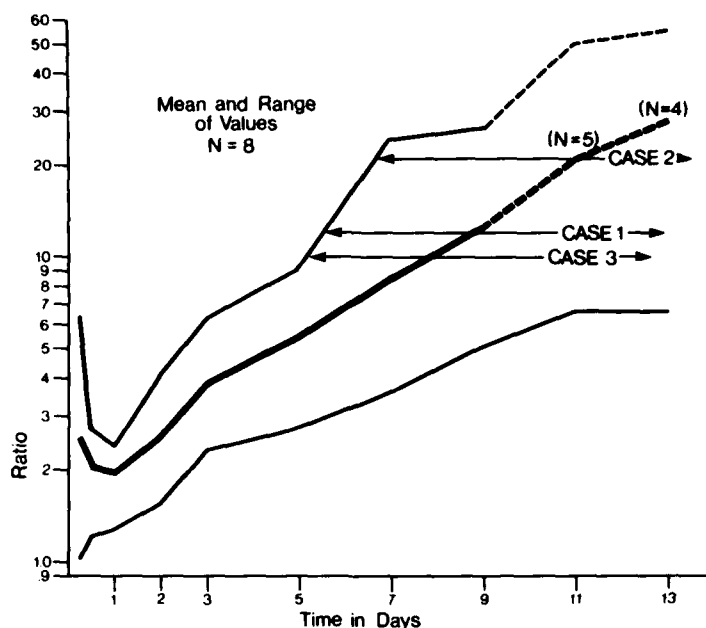


Fig. 7. Ratio of oxazepam plus desmethyldiazepam:temazepam (equivalent to ACB:MACB). Mean and range for eight subjects.

As may be seen this ratio could give ambiguous results over the first three or four days and in such a situation levels of the unchanged metabolites could be measured if a more definitive dose:time estimate were desired.

It is only during the first 6 hours that a therapeutic dose (10 mg or less) of diazepam has a measurable effect in the impairment of performance (10). In some individuals, however, a resurgence of plasma levels has been observed after this period of time causing subjects to become drowsy again. The authors suggest that this may occur through mobilization of stored diazepam or the release of active metabolites from entero-hepatic circulation (11). The hypnotic effects of a single dose of the tranquilizer thus could conceivably decrease mental alertness for up to 12 hrs. While precision in the determination of ingestion time was seldom less than a 12 to 24 hr time span, the use of metabolite ratios and concentrations does appear to differentiate between recent consumption, i.e., the first day or two, and later post-ingestion times. The relationships between metabolite ratios and ingestion time presented here represent only the single-dose situation and will not hold for multiple or chronic dosing occurring over a period of time. In such cases, however, multiple usage will be evident in considerably higher metabolite concentrations. In several instances of known chronic dosing, we have observed oxazepam levels ranging from 260 to 350 ng/mg creatinine and metabolite ratios falling between 2.0 and 3.0. It should be noted also that the data in this study apply to a male population only. The levels of metabolites excreted in a female population could be quite different with time since women have been shown to exhibit significantly longer plasma diazepam half-lives and lower clearance rates than men (12).

#### ACKNOWLEDGEMENTS

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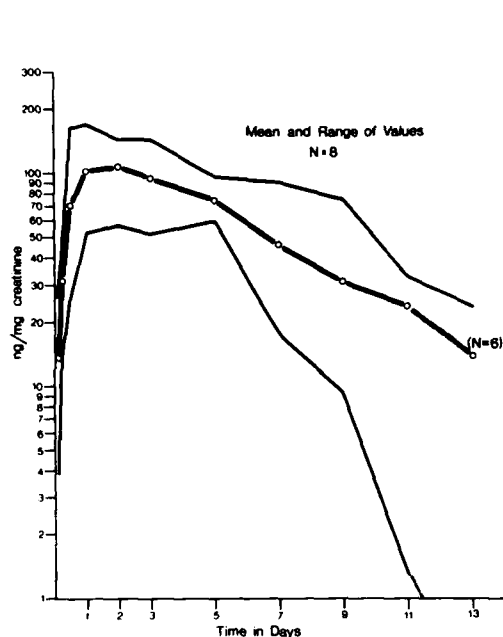


Fig. 8. Range of oxazepam levels in urine after a single 10 mg dose.

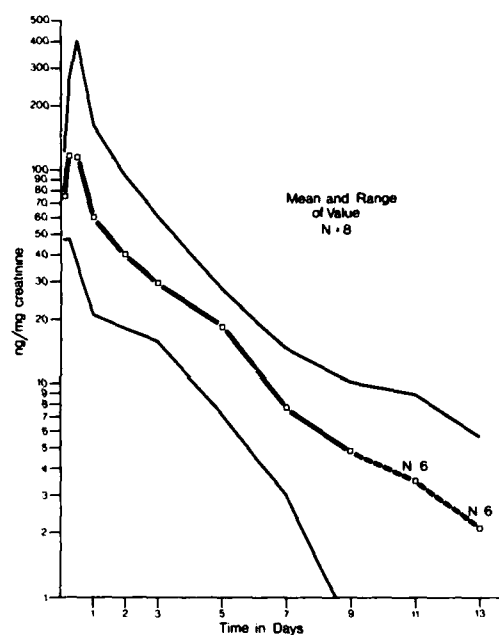


Fig. 9. Range of desmethyldiazepam levels in urine after a single 10 mg dose.

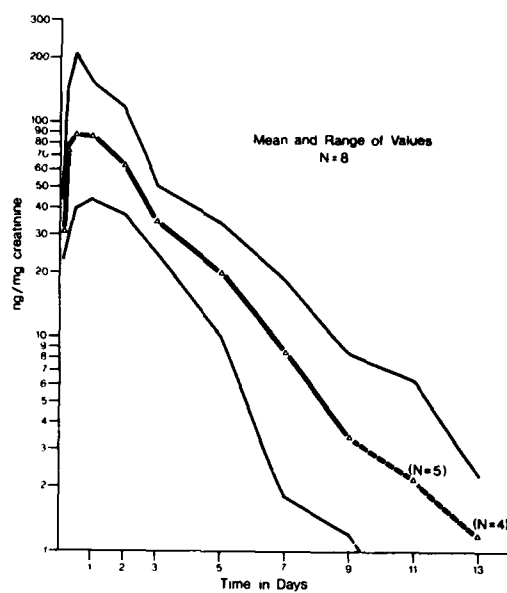


Fig. 10. Range of temazepam levels in urine after a single 10 mg dose.

## CARDIOVASCULAR RISK FACTORS IN THE PILOT POPULATION

### A POLICY DISCUSSION

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#### Summary.

Several large scale prospective investigations have recently quantified the cardiovascular risk factor pattern in the Scandinavian male population.

It is the intention of the RNOAF Institute of Aviation Medicine to put these findings to practical use. Since the small population in Norway is biologically and sociologically homogenous, it is possible to

- a) extrapolate from current epidemiological research in Scandinavia to the aircrew population.
- b) Perform periodic standardized/centralized medical examinations and evaluations.
- c) remain in close personal contact with each aircrew member throughout his total career.

A risk profile will be established for each aircrew candidate at the point of training entry, and monitored annually throughout his career. Among other medical information this will contain his family history, cholesterol/HDL ratio, smoking habits, level of physical fitness etc.

Significant changes in any individual's risk factor profile will be a cause for personal counseling and/or minor modifications/restrictions in medical flight status.

It is hoped that this pattern of aeromedical approach will reduce the problems caused by CVD in Norwegian military and commercial aviation.

#### Introduction.

According to most medical criteria the population of young military pilots is virtually free from cardiovascular disease. Similarly, the number of incidents/accidents where CVD has been a causative factor remains very low. Should we in the aeromedical community therefore rest satisfied that our screening and certifying procedures are fully adequate?

Several disturbing factors from modern CVD research force us to continually upgrade our views and regulations. We are primarily concerned with flight safety, and because of the sudden incapacitation that can quickly and unexpectedly be the first symptom of this disease, aeromedical CVD guidelines have to remain strict. As is well known CVD accounts for a majority of early adult male mortality (although a slight decline in prevalence has been reported in recent years) and a recent survey shows that CVD also constitutes the most important medical cause of flight disqualification in pilots above 35 yrs (65%). (1). However, as has been well documented by studies at the USAF School of Aerospace Medicine by R. Hickman and others (2) the evaluation of latent and unsymptomatic CVD through routine non-invasive methods, is not as reliable as was once thought. The fact is that we must go on to ground pilots and enforce major mid-life change of careers, on something which now and then is only a qualified medical estimate of risk increase. Is it possible to improve this risk assessment, and thereby keep our "false positives" flying? And correspondingly, is it possible to screen out those individuals in which true CVD develops, before they and the society have invested so much in a flying career, and thereby achieve that fewer "true positives" ever fly?

#### Prospective studies.

Several large scale Scandinavian prospective studies on urban populations in Oslo, Tromsø, Gothenburg and Stockholm have in later years established the relative quantitative importance of cardiovascular risk factors in our adult male population. In this discussion we will relate how these results are currently transferred into guidelines for trainee screening and pilot classification in the RNOAF. We think it is possible to extrapolate from this current epidemiological research to our aircrew population

- a) because the Norwegian (and Scandinavian) population is numerically small and rather homogenous both as regards life style patterns and genetical background and
  - b) because our aeromedical survey system is small and centralised and an in depth analysis of each prospective or flying pilot is possible at all times.
- The national pilot population is in itself too small for prospective research on CVD morbidity, but on the other hand constant monitoring and individual counseling can be performed. Therefore as regards prophylactic medicine the Air Force Medical Service seems to have much to offer. Also of considerable scientific interest is the fact that any discrepancies between the CVD related clinical parameters among pilots and the general population can readily be discovered. It is important for us to rely primarily on Scandinavian studies in this field, because epidemiology and sociology vary so much from country to country. A correlative study on coronary morbidity in Edinburgh and Stockholm (2) for example revealed cardiac mortality to be 3 times higher in Scottish 40 yr old men. The risk factors such as

body weight, blood (systolic and diastolic) pressures, smoking and drinking habits, physical fitness, blood lipids and serum cholesterol, ECG abnormalities etc. displayed significantly different distributions in the two cities.

#### The Gothenburg Study:

The correlation between various risk factors and subsequent development of myocardial infarction (MI) has been well brought out in the Gothenburg study (4). 7500 healthy middle aged men have been followed from age 47. A multivariate nomogram between three risk factors found to have the highest correlation with subsequent MI is shown in Fig. 1.

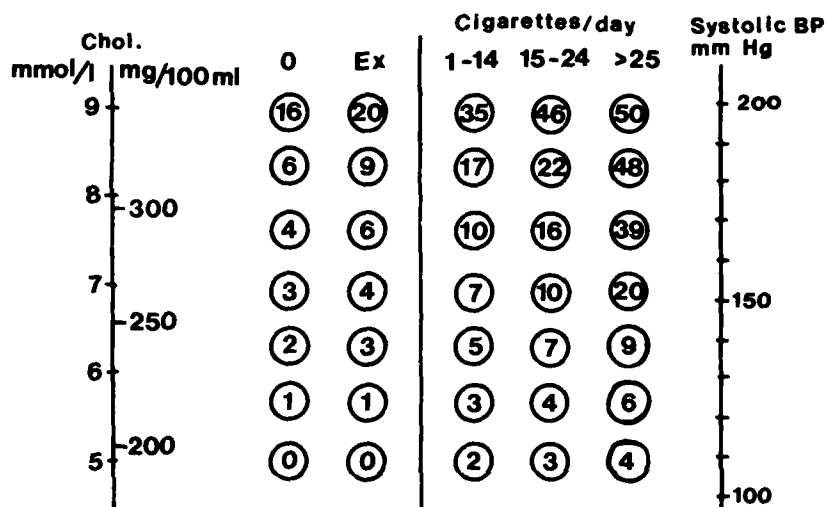


Fig. 1.

The crossing point between the BP-Cholesterol connecting line and the vertical mid line is connected horizontally to the appropriate smoking pattern column. The circled numbers then give the observed percentage of individuals who developed an MI in a 10 yr period.

In this way we can see for instance that a healthy male of age 47 who smokes more than 25 cigarettes daily, who has a systolic blood pressure of 180 mmHg, and displays a hypercholesterolemia of 9 mmol/l (348 mg/100 ml) has close to a 50% chance of coming down with an MI within the next 10 yrs. Would you fly with this pilot?

#### Assessing cardiovascular risk levels.

The question arises where on a scale prospective CVD risk do you ground a middle aged pilot. Presumably there is not much difference of opinion in the hypothetical 50% case just mentioned. But what about a borderline hypertonic (140 mmHg) heavy smoker with a wrong diet for his lipid metabolism? Even he has a 39% chance of developing MI, and we certainly feel that he should not fly without certain category restrictions. What is the "normal" in this risk evaluation?

Let us take the nonsmoking, normotensive, with an average (7 mmol/l = 271 mg/100 ml) cholesterol level. In our population he has a 2% chance of suffering an MI in the next 10 yrs. These figures relate to actual MIs actually suffered by middle aged men in Gothenburg over the last decade, the data certainly are not speculative.

If we accept pilots to fly with a 5 times ideal risk level, it follows that we must do something about the pilot who displays a risk profile that puts him in the 10% bracket over the next 10 years. What sort of man is this? From our nomogram we can deduce that an "average" heavy smoker (BP 135 mmHg, Chol 7 mmol/l, a pack daily) falls within this category. And

if he doubles his smoking he doubles his risk level. We have already instituted adjustment/restrictions in flight categories on the basis of smoking habits alone, and feel that these data bear us out in this. In fact, a hypothetical pilot who would be grounded by most services, namely the severe hypertensive (200 mmHg) nonsmoker with low serum cholesterol (5.5 mmol/l = 216 mg/100 ml) has only a 3% chance of meeting with an MI during next decade. When looked at as univariate functions there seems to be an almost linear correlation between (ongoing) smoking frequency and subsequent MI development (Exsmokers fall nearly in the same bracket as nonsmokers). Similarly the systolic BP/MI incidence plot has a near linear slope. As can be expected from newer findings, however, the effect of the serum cholesterol level is more complex, - also the Gothenburg study in its preliminary form has not yet evaluated the importance of the HDL/LDL ratio. The conclusion seems inescapable that blood chemistry and smoking habits must be brought to focus if we will attempt to judge the CVD risk level before determining a pilot's fitness for flying. Blood pressure can obviously no longer be our single parameter.

#### The Oslo Study:

Several research centers are in the process of suggesting guidelines for such risk level determination. The Oslo study (5) which is a prospective study on 16 200 men from age 40 - 49, has employed the scheme shown in Fig. 2 for preliminary evaluation.

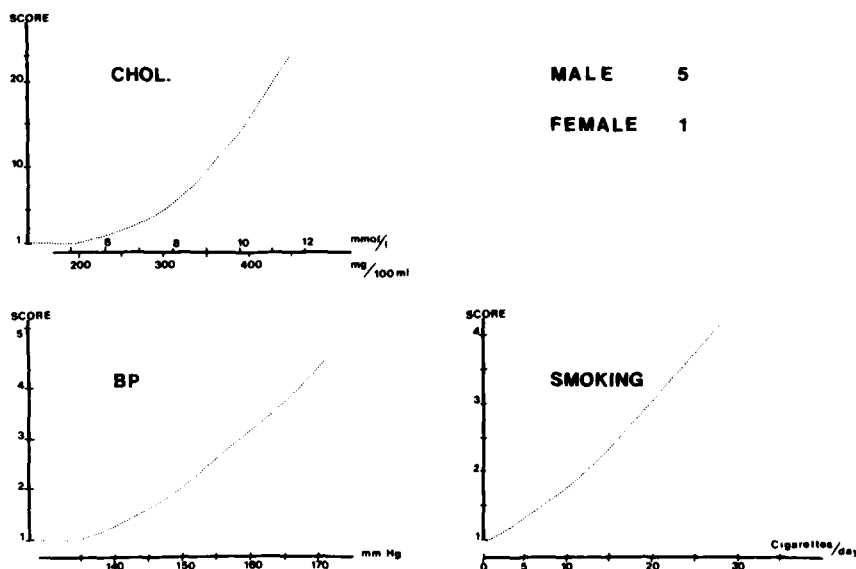


Fig. 2.

The scores for sex, smoking habits, systolic blood pressure and serum cholesterol are multiplied to give the total score. For example the hypothetical 50 yr old male previously mentioned (with a 50% MI probability) would score  $5 \times 4 \times 4.5 \times 9.5 = 855$ , whereas the so called normal (with his 2% MI probability) comes out with  $5 \times 1 \times 1 \times 3.5 = 17.5$ . These scores have demonstrated remarkable prognostic power in the 8 years that the Oslo study has been under way. Although we have not finally settled on any given risk equation, the Aeromedical Board of RNoAF has decided to establish a continuously upgraded CVD risk profile for each male in the flying community. This profile will be monitored judiciously by the board with the main emphasis on prevention of subsequent manifest CVD through individual life style counseling. Adjustments in medical flight category classification are also used when necessary. A few examples of this policy will be given later in the discussion.

We cannot hope through this limited, epidemiological effort to establish any direct proof of the effect that risk factor change might have on CVD incidence - but must as the rest of the medical community remain hopeful in this regard.



### Discussion

Let us now examine three case stories which illustrate various aspects in the shaping of our aeromedical CVD policies in Norway.

#### Case 1:

Major H.M. came to the aeromedical board's attention in the autumn of 79 when he was coming up for his annual board review. He was then a 46 years old fighter pilot, slightly overweight (179 cm, 80 kg), normotensive chain smoker (60 cig/daily). His physical fitness (measured indirectly as max O<sub>2</sub> uptake) had fallen to borderline levels (30 ml/min/kg) over the last years, and slightly elevated liver enzymes and a bout of gout some years previously had led to alcohol intake counseling. A serum cholesterol level of 325 mg/100 ml had been measured some years ago. He had varicose veins, took no exercise, and was overdue on his (mandatory) triannual aviation medicine course. The concept of risk factor level computation had not been established at this time. Today's algorithm would give him a score of  $5 \times 6 \times 1 \times 7 = 210$ , and the Gothenburg nomogram would give him an above 20% chance of an MI within the next 10 yrs. 4 weeks before his triannual board physical examination he collapsed of an acute MI while flying as a passenger in a Twin Otter commercial plane, and died the same day. The previous day he had flown an F 104. No recent complaints had been given to the local flight surgeon, but some of his colleagues had heard him talk about "giving up fighter planes".

#### Case 2:

Cpt T.N. is a 45 year old C130 H pilot. The board reviewed his annual flight physical examination in August of 79 and noted an unsatisfactory CVD risk level (again on general clinical grounds). His blood pressure which had been normal in previous years had risen to 150/90. His body weight had increased slightly (182 cm, 81 kg). An exercise ECG was normal, but his physical fitness level had been low for several years (28 ml/kg/min). His cholesterol level had been measured as 370 mg/100ml some years ago, and he smoked 25 cigarettes daily. With our tentative risk level algorithm he would score:  $5 \times 4 \times 2.5 \times 12 = 600$ , and (if he were 47) the Gothenburg nomogram would give him a 10 yr MI chance of 48%.

Since he was always flying with a copilot it was not felt that he needed to be grounded immediately, but he was given personal counseling by the local flight surgeon and informed by the board that a restricted flight category would follow within a 6 month period if the situation then was similarly unsatisfactory. 4 months later he suffered an MI while landing in inclement weather with a cargo of high explosives. The co-pilot effectuated a safe landing. The captain was hospitalized and has made an uneventful recovery. He has also given up smoking.

#### Case 3:

Lt. Col E.J. was reviewed by the board in July 80. He is a 43 yr old pilot in temporary staff position. His routine flight physical shows him to be 25% overweight (178 cm, 90 kg), his BP is 130/85, he smokes around 15 cigarettes daily, his exercise ECG is normal (a partial right bundle branch block and left axis pattern is noted of less than 5 yrs standing). Of special significance, however, is his cholesterol level (8.99 mmol/l) and his HDL concentration (.79 mmol/l) which is depressed and yields a possibly pathological (6) Chol/HDL ratio of 11.4. His triglycerides are also elevated (4.48 mmol/l).

His risk score is computed to  $5 \times 2.5 \times 1 \times 9.5 = 713$  (the Gothenburg nomogram gives 16% for a 47 yr old male with these parameters). The board has revoked his A1 category, and put him in a (medical) A2 restricted flight category which means that he is unable to be in control of any aircraft (although he may fly as a back up co-pilot). He is given a personal CVD prevention counseling, and strongly encouraged to change his diet, smoking habits etc.

Three months after the institution of these lifestyle changes his cholesterol level had dropped to 6.9 mmol/l (all tests evaluated at the same laboratory) and his HDL was 0.9 mmol/l. His chol/HDL ratio, although still elevated, has thus dropped from 11.4 to 7.7. Most significantly his smoking is now cut back to less than 10 cigarettes daily.

New testing will be conducted in another three months, and the board will then review his temporary A2 flight category.

### Pilot Selection Criteria.

Since CVD has an insidious onset, and develops in parallel with sociomedical risk factor patterns over more than two decades, it seems reasonable to perform a rather thorough CVD risk factor analysis at the stage of flight training entry. Such a policy has also been recommended by the British Civil Aviation authorities through a committee set up by the Royal College of Physicians (1). Surprisingly, apart from cases of manifest hypertension, cardiovascular risk factors seem not to have an important place in most selection and screening procedures.

Since 1980 the RNoAF Aeromedical Board has introduced guidelines in screening of its flight trainees, which include

- a) the establishing of a current CVD risk profile
- b) a thorough cardiovascular family history
- c) a serum cholesterol/lipid profile.

Labile hypertension (syst BP episodically above 145) or stable blood pressures measured repeatedly above 140/90 are causes for rejection. This criterion alone cancels out about 15-20% of our flight training applicants. Although nobody can prove that these individuals are the same 20% of the middle aged population that in our culture go on to require antihypertensive medication, it seems reasonable to employ stricter BP criteria in the 18-20 year old than we do in the group of senior commercial pilots. Furthermore a Chol/HDL ratio above 7, or a hyper-cholesterolemia concurrent with a family history of early MIs will be disqualifying, as will be an established habit of heavy smoking under otherwise borderline risk factor patterns. Echocardiograms will probably become mandatory. It is hoped that this pattern of aeromedical approach will reduce the problems caused by CVD in Norwegian military and commercial aviation.

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#### DISCUSSION

LANDOLT (Canada): What is the basis for such a marked difference in the score between men (score = 5) and women (score = 1) in the Oslo study?

ALNAES: The scoring system of the Oslo study was instituted on the basis of the known statistics on MI victims, and there still are 5 times as many male MIs as there are female MIs in our 40 to 50 age group. What is new in this study is that the risk factors you have 10 years before developing an MI have been shown to have such remarkable predictive power. For example the group of unsymptomatic 40 year olds scoring in the highest quintile, turned out to have a cardiovascular mortality rate of 12 times those in the lowest quintile, during the study decade.

GRAY (Canada): Would you ground a pilot solely on the basis of the risk factor analysis - or would you proceed with further screening, e.g. thallium or angiography?

ALNAES: Within the National Health Service we are not able to conduct either of these diagnostic investigations on wholly unsymptomatic individuals. On the other hand since our air force has a multi track classification system, we can respond very elastically to any unfavourable changes in an airman's risk profile. Temporary restrictions as mentioned in the case stories would certainly come before an actual grounding - and seem to have a very positive effect as regards positive life style changes.

ADOLPH (UK): In the prospective population studies quoted did there appear any "normal" level of smoking habit?

Was there a positive family history in the subjects mentioned in your case stories?

ALNAES: There seems to be a roughly 50% incidence of smokers among middle aged Norwegian men. Smoking frequency drops with increasing level of education. Among our young pilots there are fewer than 10% who smoke regularly, - in the flying community as a whole, the incidence may be closer to 20%. - Family histories were not positive in any of the case story subjects.

DETECTION OF CORONARY ARTERY DISEASE IN  
ASYMPTOMATIC AIRCREW MEMBERS WITH THALLIUM-201 SCINTIGRAPHY

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#### SUMMARY

Thallium-201 exercise myocardial perfusion scintigraphy was accomplished in 130 aircrew members prior to their undergoing coronary angiography. Most were undergoing cardiac catheterization for an abnormal exercise response to treadmill testing. Of these, 22 men had arteriographic evidence of obstructive coronary disease of at least 50% narrowing in a single vessel. All had abnormal myocardial scintigrams. There were 12 other aviators who had minimal degrees of coronary artery disease with lesions less than 50% as the maximum degree of obstruction. Of these, 8 had abnormal thallium scans showing a perfusion defect in the area of the myocardium, presumably supplied by the diseased coronary artery. Of the 96 men with normal angiograms, only 4 had abnormal myocardial scintigraphy. An abnormal myocardial scintigram was often associated with significant obstructive disease. A normal scan accurately ruled out the presence of high-grade obstructive lesions and missed only 4 cases of minimal coronary disease. The application of gated thallium myocardial perfusion scans in the practice of aerospace cardiology has important significant applications for followup of therapeutic modalities as well as screening for evidence of myocardial ischemia in apparently healthy aircrew members.

#### INTRODUCTION

Coronary arteriosclerotic heart disease is the major nontraumatic cause of death in USAF aircrew members. Approximately 50% of all referrals to the Aeromedical Consultation Service of the USAF School of Aerospace Medicine are for potential cardiovascular problems. The majority of these are referred for electrocardiographic abnormalities discovered either at rest or exercise. Until recently, exercise electrocardiography was used as a screening technique for the presence of latent asymptomatic coronary artery disease in these apparently healthy men and for clarifying the significance of nonspecific electrocardiographic abnormalities. In our experience, an abnormal electrocardiographic response to exercise is associated with the risk for subsequent coronary events that is 14 times greater than men with normal stress electrocardiograms (1). Although an abnormal stress electrocardiogram identifies many individuals at risk, only 20 to 40% of aircrew members who undergo coronary arteriography because of an abnormal stress test have arteriographic coronary artery disease (2, 3). Obviously, mislabelling so many "false positives" as having asymptomatic coronary artery disease is counterproductive from a legal, psychological, and aeromedical standpoint. Radioactive tracer techniques which allow identification of jeopardized myocardium or myocardial scar, have provided a new approach to the noninvasive assessment of coronary artery disease (4, 5, 6, 7). Myocardial imaging with thallium-201 at peak stress and again at reperfusion has been shown to be an accurate means of detecting coronary artery disease in symptomatic populations (5-9). A previous report (10) from this laboratory concluded that thallium myocardial scintigraphy could not replace coronary arteriography in the diagnosis and evaluation of disease progression in asymptomatic aircrew members. Since that time, major advancements have been made in the processing of thallium myocardial images at USAFSAM in the evaluation of regional blood flow. The distribution of the radioactive tracer within the myocardium is dependent upon regional blood flow, its extraction by the myocardium, and its net efflux. At rest, its distribution is uniform unless there is a significant high-grade obstruction or previous loss of myocardial cells due to a myocardial infarction represented by a "cold spot" on the scintigraphic image. Coronary obstructive lesions which do not compromise coronary blood flow at rest can be detected if the tracer is administered when the myocardial demand resulting from exercise stress exceeds the coronary artery reserve. Resting defects, which increase in size as a result of exercise, suggest the presence of additional ischemia in the area of a myocardial infarction.

To determine whether thallium-201 myocardial perfusion scintigraphy is a useful screening tool in an asymptomatic population with very low pretest likelihood of disease, single dose stress and delayed thallium-201 scintigrams were performed in asymptomatic USAF aircrew members who were undergoing evaluation at USAFSAM. The purpose of this study was to reevaluate the usefulness of thallium scintigraphy in excluding the diagnosis of coronary artery disease and possibly precluding the need for coronary angiography.

#### METHODS

**Patient selection:** The patients were 130 aircrewmen who were studied with coronary arteriography because of serial electrocardiographic abnormalities, usually ST-T wave changes, and/or an abnormal ST segment response to maximal exercise stress testing. Those aircrew members who were found to be free of significant coronary artery disease were returned to flying duty while the remainder were removed from active flying status for aeromedical safety reasons. All patients were free of any symptoms suggestive of angina pectoris, and further denied any clinical problems related to the cardiovascular system upon meticulous history-taking. All 130 patients were men whose mean age was 41.6  $\pm$  4.9 years (range 32-56 years). No patient had clinical or electrocardiographic evidence of a prior myocardial infarction and none were receiving medications.

**Exercise testing protocol:** All exercise tests were performed after an overnight fast. The patients completed a symptom-limited treadmill exercise test using a constant treadmill speed of 3.3 miles per hour with the incline increasing by 5° every third minute. Electrocardiographic data from leads I, II, III, aVR, aVL, aVF, V1, V2, V3, V4, V5, and V6 were recorded continuously on electrocardiographic paper and analogue magnetic tape. The entire treadmill was reviewed minute by minute during the following conditions: pre-exercise, supine, standing, and hyperventilation; throughout exercise; and during at least 8 minutes of recovery. All patients were encouraged to exercise to their maximal effort. Nearly all patients achieved 85% of the predicted maximal heart rate for

their age, with only 5 patients stopped by the monitoring physician because of marked (greater than 0.4 mv) ST segment depression at submaximal levels of stress. All other patients were exercised to symptoms of breathlessness or leg fatigue, and none complained of chest pain. All exercise electrocardiograms were of good quality and none were considered uninterpretable.

The resting and stress electrocardiograms were interpreted in a blinded fashion by two cardiologists without knowledge of angiographic or scintigraphic results. The stress electrocardiogram was classified as positive for ischemia if there was horizontal or downsloping ST segment depression of 0.1 mv or more at least 80 msec from the J point. If ST segment changes were present at rest, an additional 0.1 mv of ST segment depression beyond the baseline ST segment level was required to label the test as abnormal.

Scanning methods: Myocardial perfusion scintigraphy was performed on all 130 patients on the day following routine maximal exercise tolerance test. After an overnight fast, an intravenous line was inserted percutaneously into an antecubital vein and kept patent with an intravenous infusion of normal saline. A repeat exercise test was performed using a protocol identical to the previous day's test. Two mCi of thallium-201 were injected approximately one minute before the maximum stress that was achieved on the previous day's treadmill. The thallium dose was flushed with 10 cc of normal saline and the patient was encouraged to continue walking for one minute after injection. No recovery tracings were obtained unless a significant stress arrhythmia occurred in the last minute of exercise. Myocardial scintigraphy was initiated within 6 minutes after the thallium injection. The patient was placed supine and images were recorded in the anterior, 22° LAO, 45° LAO, and 67° LAO positions, using a single crystal scintillation camera (Searle PhoGamma IV) equipped with a high sensitivity collimator. The images were recorded with the 3 windows of thallium activity encompassing the mercury x-rays as well as the gamma emissions. Immediate postexercise images in each view were obtained for a preset interval of 360 seconds in the gated mode, yielding a total accumulation of 500,000 to 700,000 counts in the entire image, with approximately 250,000 to 375,000 counts over the myocardium.

Multigated imaging sequences were collected at 15 msec per frame by means of a physiologic synchronizer (Brattle Instruments) interfaced with a digital computer system (Medical Data Systems - Modumed). Each R wave was regarded as the beginning of a cardiac cycle. The acquisition program measured the average R-R interval over several hundred cycles, repeated in all four projections. The gated thallium scan was linearly amplified to 1.7 times normal, yielding an effective resolution of 109 x 109 matrix points for presentation. Contrast enhancement was performed by a floating 9-point smooth and background subtraction was automatically performed by a computer algorithm in which the background counts were determined outside the areas of the right and left ventricular images. Background subtraction was never more than 25%. The delayed and exercise images were normalized automatically to the region of maximal count density in the initial scans. The scintigraphic images were acquired directly into the computer core and replayed from the computer after the study was completed. The computer created multigated images and presented them either as a composite of end-systolic and end-diastolic frames or end-diastolic and end-systolic images presented as synchronized serial images in a cinematic format in differential color graphics.

Interpretation of myocardial scintigrams: The myocardial perfusion images were reviewed on the videoscreen with the initial and delayed images displayed side by side for comparison in each projection. Two independent observers interpreted the scans prior to angiography. Disagreements in interpretation were discussed and a final reading agreed upon. Each region of the myocardium was subjectively scored as to visual count density. A reversible defect was defined as an improvement in the tracer activity from postexercise to delayed images in any ventricular segment. A persistent defect was interpreted as representing a myocardial scar. Small static defects seen at the apex were common and were always considered normal unless they represented an area of reversible ischemia associated with a larger static or reversible filling defect in an adjacent wall of the myocardium.

Coronary angiography: Selective coronary arteriography was performed in multiple projections using the Judkins technique. The angiograms were read blindly, without knowledge of the clinical findings. The patients were considered to have significant coronary artery disease if one of the major coronary arteries or its branches had a 50% or greater narrowing of the diameter of the vessel. This classification was a result of a consensus of two observers.

#### RESULTS

The results from the entire study group were summarized in Table I. The 130 patients were classified into three groups based on the results of coronary angiography. Group I consisted of 96 patients (74%) with a completely normal selective coronary angiogram, but with abnormal, symptom-limited exercise tolerance test. Of these, 92 had normal stress and delayed thallium scintigrams without evidence of reversible ischemia or static myocardial perfusion defects. Four thallium scintigrams in Group I were falsely positive. The most common area associated with the false positive scan was the inferior septal wall in the 22° LAO projection. This particular defect was seen on 3 scintigrams, with the other false positive defect seen in the septal region on the 45° LAO projection. There were no anterior or strictly inferior wall false positive defects.

Table I. ANGIOGRAPHIC GROUP

	Group I NORMAL	Group II MINIMAL CAD	Group III CAD
Thallium scintigraphy			
Abnormal	4	8	22
Normal	92	4	0

Group II consisted of 12 men with minimal or subcritical coronary artery disease (less than 50% luminal diameter stenosis in a single vessel). Group II had equivocal results on thallium myocardial perfusion scintigraphy. Eight of these patients (75%) had a reversible perfusion defect in the area of myocardium distal to the minimal coronary stenosis. Three of these 8 patients had 2 perfusion defects on thallium scintigraphy which correlated with double vessel minimal coronary lesions. The remaining 5 abnormal thallium scintigrams

revealed inferior wall ischemia, which was associated with minimal coronary artery disease of the right coronary artery. Four cases of subcritical coronary artery disease had normal thallium scintigrams.

Group III, the 22 patients with significant coronary artery disease, all had abnormal thallium scans. Of these, 2 patients had single vessel disease, 11 had double vessel disease, and 9 had triple vessel disease. When the myocardial scintigrams were evaluated region by region, all but one significant coronary artery stenosis were associated with an appropriately located perfusion defect in the left ventricular region. One patient with double vessel coronary artery disease had an 80% lesion in a large diagonal branch of the left anterior descending coronary, which was unassociated with a perfusion abnormality. However, the scintigram in this patient was abnormal, showing an inferior wall perfusion defect associated with a 60% narrowing of the right coronary artery.

The standard statistical calculations from these data are presented in Table II.

Table II. DEFINITION OF ABNORMAL

	Group I Normal + Minimal CAD (n=108)	Group II vs CAD (n=22)	Group I Normal vs Minimal CAD + CAD (n=96)	Group II vs Minimal CAD + CAD (n=34)
Sensitivity	22/22	100%	30/34	(88%)
Specificity	96/108	89%	92/96	(96%)
Predictive value	22/34	65%	30/34	(88%)
Prevalence of disease	22/130	17%	34/130	(26%)

Post-test likelihood of disease if test is:

Normal	0%	4.2%
Abnormal	63%	80%

Three asymptomatic men with significant coronary artery disease were discovered to have suffered a silent inferior wall myocardial infarction. None of these men had significant electrocardiographic Q waves and none of them had a previous event suggestive of a myocardial infarction. All had shown inferior or inferior-posterior static defects on thallium myocardial perfusion scintigraphy which correlated with a 100% occlusion of the right coronary artery and an akinetic segment of the inferior or posterior wall on left ventriculography.

#### DISCUSSION

One of the most important applications of noninvasive tests to detect reversible ischemia is in the evaluation of those patients who have no historical or objective evidence of coronary artery disease. Detection of coronary atherosclerosis in asymptomatic patients offers clinicians the opportunity to assess the natural history of coronary artery disease and possibly intervene with preventive measures before the onset of clinical events. Given a clinical level of suspicion for disease, the selection of which diagnostic test to perform depends not only on the probability of disease within the population, but also upon the likelihood of disease being present if the test is abnormal (11). In clinical medicine, it is often unwise to extrapolate from findings in one population to another, especially when comparing data from hospitalized patients to an asymptomatic group. Therefore, the predictive accuracy of each test should be determined on the population in question.

The most common noninvasive method to detect coronary artery disease is abnormal ST segment response to exercise electrocardiography. Unfortunately, the predictive value of the ST segment response is 30-45% in an asymptomatic population, as compared to a much higher predictive value reported in studies of patients evaluated for chest pain (1-3, 12). Recently thallium myocardial perfusion scintigraphy has been used to determine whether an abnormal stress test or a chest pain syndrome is due to coronary artery disease. Preliminary results with small numbers of patients have suggested that myocardial scintigraphy has a much higher predictive value than stress electrocardiography in asymptomatic patients. Hamilton, et al, recently applied Bayes' theorem to the results of thallium scintigraphy to define its usefulness and limitations in coronary artery disease (13). His study was based on clinical studies which were combined and compared their results to the electrocardiographic response to exercise testing to stress thallium-201 myocardial perfusion scintigraphy. These and other investigators have concluded that patients with classic angina pectoris are not candidates for thallium scintigraphy because the probability of disease in this population is so high that the results of perfusion scintigraphy add little useful diagnostic information since the probability of disease in these patients is high (13-15). Other authors have felt that the same theoretical considerations would lead one to conclude that screening for coronary artery disease with thallium scintigraphy in an asymptomatic population, even if the stress electrocardiogram is abnormal, is likewise unwarranted (13-17).

In the present study, the predictive value of thallium scintigraphy was increased to 65% over exercise stress testing alone, representing a marked improvement over the predictive value of stress testing alone. This improvement was seen in a population without previously recognized myocardial infarctions, although three patients had fixed perfusion abnormalities and were found to have akinetic segments on ventriculography. Recently the application of thallium scintigraphy has been deemed most appropriate in selective subgroups of patient populations. Data from Hamilton, et al, suggested that thallium scintigraphy is most useful in patients with a pretest likelihood of disease in the range of 40-80% (13). These investigators concluded that with a disease prevalence of 20%, the probability of disease was less than 50% using a combination of both ST segment abnormalities on exercise testing and the presence of thallium scintigraphic defects as

their diagnostic criteria. Other authors have felt that thallium scintigraphy is useful in the evaluation of those with atypical chest pain syndrome in order to rule out the diagnosis of coronary artery disease (16, 17, 19-21). McCarthy and associates (17) recently reviewed their experience with patients with inadequate treadmill tests defined as those who did not reach 85% of maximum predicted heart rate, those with intraventricular conduction defects, or those with exercise-induced chest pain but no ST segment depression. They found that thallium scintigraphy improved their predictive accuracy in these patients, but was not more accurate than exercise electrocardiographic criteria alone when the treadmill test was adequate and diagnostic. Similar studies (16, 20) have concluded that thallium scintigraphy is primarily indicated for patients with inadequate, uninterpretable, or equivocal stress tests.

Unlike previous studies, our patient population was asymptomatic and thus had a low prevalence of significant coronary artery disease. However, all had an abnormal ST segment response to symptom-limited exercise electrocardiographic stress testing. None of our patients were taking propranolol, digitalis, or other preparations and all had normal serum potassium, all of which would be likely to affect the interpretation of ST segment response to exercise. None had any electrocardiographic abnormalities such as left bundle branch block which make the tracing uninterpretable. Initially, it was assumed by us that the sensitivity of thallium scintigraphy in our population would be less than that as reported by others. However, the high sensitivity and specificity found in this population suggested thallium scintigraphy can be used accurately to detect coronary artery disease in an asymptomatic population. It may also be used to determine whether or not certain subsets of patients with no symptoms or probable nonischemic chest pain syndromes should undergo coronary angiography. Importantly, we found that a normal thallium-201 myocardial perfusion scintigram was reliable in excluding the diagnosis of significant coronary artery disease in asymptomatic patients who have an abnormal ST segment response to exercise.

Our results correlate well with the small numbers of asymptomatic patients in other studies who had catheterization findings correlated with perfusion scintigraphy (22-25). The prevalence of coronary artery disease in the other studies referenced ranged from 33-71%, with an overall prevalence of 55% combining all studies. The results of thallium scintigrams were extremely accurate, documenting a perfusion defect in 34 of 36 patients with coronary artery disease. The prevalence of disease in our population (17%) was much lower than in any of the previous studies, and yet the predictive accuracy of thallium perfusion defects was quite comparable.

The patients in group II, those with minimal or subcritical coronary stenoses, had equivocal results with myocardial perfusion scintigraphy. Recently, Massie, et al (26), reported that perfusion abnormalities were much more likely to be present on thallium perfusion images if they were associated with severe stenoses rather than moderate or minimal lesions. Most clinical studies would include such patients in the normal category. Mews, et al (27), reported their experience with 13 patients with coronary artery narrowings between 30-45% in a single coronary vessel. Seven of their patients had appropriately located defects on thallium scintigrams. Pohost, et al (28), had similar results with 10 of 18 patients with 25-50% lesions having an abnormal thallium scan. In addition, 12 of 48 patients with lesions less than 25% had an abnormal myocardial perfusion image. In our study, 8 of the 12 men with minimal coronary artery disease had abnormal thallium exercise images in a distribution appropriate for the involved vessel. The specificity of perfusion scintigraphy is lowered when patients with isolated minimal coronary artery disease are included in the control group. Although these lesions have been assumed to have little clinical importance, it has been documented that less severe coronary artery stenoses can be associated with impaired blood flow during conditions such as exercise which affect coronary vascular resistance (29). Thus, it may be inappropriate to classify these abnormal thallium scans as "false positive scans" since decreased coronary artery perfusion has been described with such subcritical lesions using Xenon-133 washout techniques (30). The clinical significance of such stenoses is uncertain and actually may reflect an underestimation of the angiographic significance of disease, since the reliability of arteriograms in differentiating subcritical from significant lesions is not known.

Thallium scintigraphy can be used serially to follow patients with minimal coronary artery disease that have been allowed to fly under USAF medical service waiver policies. This modality appears to be an ideal method to follow these patients on an annual basis and, hopefully, to be able to detect any significant change in their functional coronary artery disease. In addition, newer techniques in therapy for moderate degrees of coronary artery disease, including the possibility of percutaneous transluminal angioplasty in the future, could be readily followed on an annual basis using thallium scintigrams. With the high prevalence of false positive ST segment responses to exercise occurring in asymptomatic aircrew, the use of thallium scintigraphy should be considered as an alternative to performing coronary angiography in asymptomatic aircrew members with abnormal treadmill tests but normal thallium scintigrams. The current standard of practice at USAFSAM in patients under the age of 35 with no other recognizable coronary artery disease risk factors has been to forego coronary arteriography if myocardial perfusion scanning was normal.

#### CONCLUSION

Gated thallium myocardial scintigrams accurately separate asymptomatic men with abnormal treadmills into those with and without coronary artery lesions. Gated thallium scintigrams can identify minimal coronary artery disease and gated thallium scans presented in a cinematic format accurately augment the treadmill in the discovery of latent coronary artery lesions. The application of gated thallium myocardial perfusion scintigraphy in the practice of aerospace cardiology appears to have a bright future and many important applications for followup of newer therapeutic modalities as well as the detection of latent coronary artery disease in aircrew members in which aeromedical safety is paramount.

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PILOTS WITH CARDIOLOGICAL PROBLEMS:  
TEN-YEAR FOLLOW-UP

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SUMMARY

Seventeen pilots of the Hellenic Air Force and twenty two Airline pilots are maintained on flying status although presenting with the following heart problems: Left anterior hemiblock (7),left anterior hemiblock with incomplete right bundle branch block (4),complete right bundle branch block (2),first degree atrioventricular block (1),coronary sinus rhythm (2),multiple ectopic atrial beats (4),ectopic ventricular beats (1),repolarization changes with negative exercise testing (9),arterial hypertension under therapeutic control (5),old myocardial infarction with successful revascularization (2),old anterior infarction with normal right and circumflex coronary arteries (1),and mild aortic insufficiency (1).None of these cases presented additional abnormality and/or cardiac event during the follow-up period.

INTRODUCTION

It is well known that a number of flyers with cardiological problems,such as repolarization changes,conduction defects,rhythm abnormalities,hypertension,are maintained on flying status if the successive complete medical evaluation is normal.The Follow-up of these flyers for an indefinite period of time is important because it gives the possibility to follow the physical history of cardiac abnormalities in a select group of subjects.In this study,we reviewed the medical files of active Airline pilots and Hellenic Air Force Flyers,in order to determine a) how many are maintained on flying status although presenting with cardiac abnormalities and b) the evolution of these abnormalities.

MATERIAL AND METHODS

In Greece,Airline and HAF pilots are subjected to a periodic medical examination every six and twelve months,respectively.Flyers with cardiological problems are admitted to the hospital for a thorough medical evaluation.A number of these flyers with cardiac abnormalities,including repolarization changes,arterial hypertension,conduction and rhythm abnormalities,valvular disease,are maintained on flying status if the ensuing medical evaluation is normal.The flying status of these flyers is contingent on successfully completing non-invasive reexaminations at the HAF Aeromedical Center.In this study we reviewed the medical files of active Airline and HAF pilots.The earliest year in which complete records were available for review was 1969.Information derived from each file included age,flying status,cardiac diagnosis,evolution of cardiac abnormality.The following major diagnostic categories were utilized for this report;

- 1) Atherosclerotic heart disease,2)Hypertensive disease,3) Cardiac rhythm abnormalities,
- 4) Conduction defects,5) ECG repolarization changes,6) Valvular heart disease.

RESULTS

Tables 1 & 2 present the number,age and years of follow-up of Airline and HAF pilots with heart problems.Conduction abnormalities were noted in 14 cases (18 %);



seven cases had left anterior hemiblock, four left anterior hemiblock with incomplete RBBB two complete RBBB and one had first degree A-V block. The follow-up period was 5 to 10 years and none of these cases developed any progression. The subjects with LAH and LAH with incomplete RBBB were not subjected to any kind of specific medical examination. Rhythm abnormalities were noted in 7 cases. The follow-up period was 5 to 10 years. None of these subjects with atrial and/or ventricular premature beats presented coronary disease or any other abnormality during the observation period. Repolarization changes with a negative history for angina and negative exercise testing were found in 9 cases (0,6%). During the follow-up period of 4 to 10 years, one asymptomatic subject presented with a positive exercise testing and the performed angiogram showed a 90% obstruction of the right coronary artery.

Mild arterial hypertension (150/100 to 170/110), controlled by therapy, was noted in 5 cases. All these subjects have been granted waivers to continue flying duties for the past 5-8 years. An Airline pilot 50 years old had an anterior myocardial infarction six years ago. Angiography showed obstruction of the left anterior descending artery with recanalization, and normal right and circumflex coronary arteries. Since that time, the pilot has been on flying status. A new angiogram was performed last year, which did not show any progression of the disease.

Two Airline pilots with an old myocardial infarction underwent a by-pass operation. Two years later, they were granted waivers based on the angiographically proven patency of the grafts and on the normal response to their exercise testing. During the observation period (1-2 years), no abnormality was noted.

Mild aortic insufficiency was found in one airline pilot 38 years old three years ago. This man was symptom-free and his exercise testing showed normal cardiac performance and functional capacity. Since then, he has been returned to flying status and no evidence of decompensation was developed.

#### DISCUSSION

This study showed that certain flyers with cardiac abnormalities were on flying status for a period of one to ten years. Conduction abnormalities were the most frequent finding. Left anterior hemiblock, probably due to progressive fibrodegenerative disease of the human atrioventricular conduction system, did not show any change over a 4-8 year period. None of the cases developed coronary disease or any other abnormality.

In a population study of 8,000 Japanese-American men, aged 45-69 years, left anterior hemiblock was found in 4.1%. The incidence of coronary artery disease, fatal or nonfatal, in this group during the observation period of 3-6 years was not significantly different from that of control groups of normal men.

The progression of bifascicular block to advanced or complete A-V block has been observed by many workers. The reported incidence of progression has ranged from 1-62% in a large number of retrospective studies on the natural history of bifascicular block (1,2).

In our study, four cases had incomplete RBBB and LAH, and these cases cannot be considered exactly as bifascicular block. None of these cases progressed to advanced block.

Populations surveys have revealed a higher incidence of organic heart disease in those patients having bundle branch block, than would be expected among normals (3, 4). Much controversy exists, especially on the significance of RBBB. It has been considered as physiologic by some and, on the other extreme, to represent asymptomatic coronary heart disease by others (5, 6). In a follow-up study of 54.9 month duration, only 1 out of 59 patients with RBBB developed symptoms suggestive of coronary heart disease, while 32 out of 37 had normal coronary arteriograms (6). In our study, two patients with acquired RBBB did not develop any additional abnormality during a follow-up period of 7-8 years.

Subjects with PAC's, PVC's, prolonged P-R interval and coronary sinus rhythm, did not also show any abnormality during the observation period of 4-10 years.

The importance and prognosis of premature beats poses a difficult problem for the physician during flying fitness tests. Long term examinations, lasting 24 hours, revealed premature beats in 48% of healthy subjects, which were of ventricular origin in 29% and of supraventricular origin in 19% of all cases (7). Hiss also found ventricular extrasystoles in 0.8% of 122,000 asymptomatic USAF personnel, between the ages 16 and over 50 years (8). In some apparently normal persons, ventricular extrasystoles may persist, even in the form of bigeminy, for many years. Hinkle et al., also, found ventricular extrasystoles in the majority (62%) of 300 actively employed middle-aged men monitored for a period of 6 hours (9).

Our policy allows flyers with unifocal ventricular beats, decreasing during exercise, to continue flying.

First degree A-V block is a disturbance of conduction which may be functional as well as organic in its etiology. Prolonged P-Q intervals are found in apparently normal persons. In their survey of over 67,000 asymptomatic USAF personnel, Johnson et al. found 350 examples of first degree A-V block, or 5.2 per 1000. Twenty percent of them had P-Q intervals that were over 0.24 s (10). Of 19,000 young aircrew applicants, 59 had P-Q intervals of 0.24 s or greater (11).

From 9 asymptomatic individuals with repolarization changes and negative exercise testing, only one progressed to coronary artery disease. Experience has demonstrated a high degree of correlation between an abnormal electrocardiographic response to the maximal exercise stress testing and the subsequent development of coronary artery disease. Conversely, the presence of a negative test response distinguishes those individuals with a very low probability of such events (12). Our policy allows subjects with nonspecific T-wave changes and varying degrees of ST segment depression to continue flying, provided their clinical examination and their ECGraphic response to maximal treadmill exercise stress testing are normal.

USAF regulations now permit waiver for flying duties in individuals being treated for mild, uncomplicated hypertension, with chlorothiazide (13). In our study, 3 cases treated with chlorothiazide and 2 cases with beta-blockers, did not develop any complication during 5-8 years of follow-up.

Myocardial infarction is a cause for grounding. Our policy is: Airline pilots with M.I., with or without revascularization, to be grounded for two years and then to be submitted to coronary angiogram and maximal exercise testing. If the results are normal, pilots are granted waivers. Laurie et al. showed that the survival rates of surgically treated patients with reasonable preoperative left ventricular function, are restored to survival rates comparable with those of the general population (14).

In our study, one pilot with an old anterior myocardial infarction and normal right and circumflex arteries, has been on flying status for six years. Also, two pilots with myocardial infarction and successful revascularization, for 1-2 years.

Prior to 1960, aortic insufficiency was considered as a condition which precluded flying duties. Later, pilots with mild aortic insufficiency and good ventricular function were permitted to resume flying duties. The follow-up of 27 pilots with mild aortic insufficiency at the USAF School of Aerospace Medicine, showed that 24 pilots were still on flying status, after 38 months. (15)

In conclusion, our study showed that a number of Hellenic Air Force and Airline pilots with LAH, LAH with incomplete RBBB, complete RBBB, PAC's, PVC's, repolarization

changes, arterial hypertension, myocardial infarction with successful revascularization, did not develop any additional abnormality on any other cardiac event during one to ten years of follow-up.

The small number of cases in our series may not lend itself for statistically significant conclusions. However, our results imply that pilots with the aforementioned cardiac abnormalities may reasonably be considered for waivers.

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TABLE 1. HAF PILOTS WITH HEART PROBLEMS

Heart Problem	No	Age (Range)	Years of Follow-up
1. Conduction defects.			
a. LAH	5	32-41	5-8
b. LAH with incomplete RBBB	3	29-32	7-10
c. RBBB	1	45	8
d. Prolonged PR interval	1	49	5
2. Rhythm abnormalities.			
a. PAC's	2	38-41	5-7
b. PVC's	1	35	8
c. Coronary sinus rhythm	1	39	5
3. Repolarization changes.	2	35-42	5-6
4. Arterial hypertension.	1	45	5

TABLE 2. AIRLINE PILOTS WITH HEART PROBLEMS

Heart Problem	No	Age (Range)	Follow-up(Yr.)
1. Conduction defects.			
a. LAH	2	48-57	6-8
b. LAH with incomplete RBBB	1	44	7
c. RBBB	1	30	7
2. Rhythm abnormalities.			
a. PAC's	2	38-44	5-10
b. Coronary sinus rhythm	1	46	5
3. Repolarization Changes.	7	48-60	4-10
4. Arterial hypertension.	4	42-51	5-8
5. Atherosclerotic disease.			
a. Infarction	1	50	6
b. Infarction, by-pass operation	2	47-50	1-2
6. Valvular disease.			
a. Aortic insufficiency	1	38	3

## DISCUSSION

DR G W GRAY (CA)

1. Could you clarify what proportion of fascicular blocks was congenital as against acquired?
2. What screening procedures were used to rule out coronary heart disease?

AUTHOR

1. I cannot provide an exact answer since our ECG repository was only established in 1969. In all probability the two cases of complete RBBB were congenital, and the three cases with LAH and incomplete RBBB were acquired.
2. Screening procedures are comprised of a resting ECG and maximal exercise testing.

# USE OF BETABLOCKADE IN THE TREATMENT OF AIRCREW WITH HYPERTENSION

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## Introduction

The use of drugs which blockade beta adrenergic receptors began about 16 years ago as a treatment for angina and ischaemic heart disease. In 1964 Prichard and Gillam (1) first reported the effectiveness of these drugs in the treatment of hypertension. At that time there was no great interest but the comparative lack of side effects of betablockade therapy subsequently led to their increased use for hypertension until by 1974 they became the first choice therapeutic agents in a number of centres in Europe and later in USA. This lead has been maintained by the development of beta-one receptor specific drugs and by the therapeutic advantage of new compounds requiring only a single or twice daily dose to maintain 24 hour control.

## Hypertension and Aircrew

For many years there has been a developing dilemma in the management of aircrew with raised blood pressure. On the one hand there has been the recognition that hypertension confers a definite increased risk for sudden incapacity which is much increased by the coexistence of other risk factors for ischaemic heart disease (IHD) and for cerebrovascular disease. On the other hand there has been the difficulty of allowing the early treatment of aircrew with hypotensive drugs without compromising their fitness to continue flying. Pickering (2) in his classic work on raised blood pressure has pointed out that there is no level of blood pressure which separates health from disease and that even within any so called range of normal values those with the higher levels have a poorer prognosis than those with the lower levels. Nevertheless it has been a practical necessity to issue some set of guide lines for blood pressure in aircrew in order to have standards of reference for medical boards and medical examiners. The most widely used of these guide lines was originally proposed by the Bethesda Conference of 1975 (3) and subsequently confirmed by the Royal College of Physicians of London in 1978 (4). The table shows that these are age related. The diastolic values refer to the fifth phase of the Korotkoff sounds where this is clear cut. The "adjusted levels" refer to those acceptable in an individual in whom investigation has shown no target organ damage or associated risk factors.

Table

Age	Unadjusted	Adjusted
20-29	140/90	-
30-39	145/90	155/95
40-59	155/95	165/100

Many clinicians have criticised these guide lines as too generous and perhaps including a number of cases who would ideally be treated at these levels. This is compounded by the natural tendency of physicians to underestimate blood pressure when they are aware that a finding above set levels may lead to the end of the pilot's career. While the use of instruments providing written or digital recordings or those with a random zero level might provide more objective evidence there would still be a predictable reluctance to start a treatment that would jeopardise a career. But there is also the danger that prevarication and delay may lead to target organ damage and in 1978 Cooke and Joy (5) reported six such cases in civil professional pilots in whom long observed mild hypertension without treatment became rapidly accelerated and severe with serious consequences to their health and obviously an absolute end to their flying careers. Clearly there is an important requirement for an effective treatment which can be started in mild cases of raised blood pressure without a clear threat to flight safety or the efficiency of the individual.

## Accepted methods of management of hypertension in aircrew

These can be generally itemised as follows:

- a. Adequate investigation for
  - (1) causal factors.
  - (2) target organ damage.
  - (3) associated risk factors.
- b. Weight reduction where indicated. Avoidance of "voluntary risk factors", eg smoking.
- c. Continued observation and decision as to the need for diuretic therapy.
- d. Imposition of any waiver or restriction of medical category required by the civil or military medical authority.

Investigation as to causal factors can be very prolonged and expensive. It is also remarkably unproductive in a group of subjects repeatedly previously screened by regular aircrew medical examinations. Other than renal disease which is extremely rare in these individuals the search for target organ damage tends to concentrate on eliminating the presence of IHD. Associated risk factors such as smoking, significant

degree of overweight, and hyperuricaemia and hyperlipidaemia, continue too commonly despite all health education programmes. Perhaps service aircrew in particular feel the other risks in their lives to be more immediate.

Weight reduction may produce some fall in blood pressure but the tendency often remains and certainly the need for continued observation is paramount. The use of thiazide or spironolactone diuretics has been almost hallowed by time as a treatment for aircrew despite their known side effects which may occasionally be disabling. These include:

Thiazides:	Hypokalaemia Hyperuricaemia Diabetogenic effects Cramps
Spironolactone:	Gynaecomastia

Thiazides and Spironolactone or amiloride are frequently combined to produce a potassium sparing diuretic effect. The real reason why these compounds have found acceptance in the treatment of aircrew is the lack of any action on the central nervous system as opposed to such drugs as Methyldopa, Clonidine or Reserpine and the absence of any significant postural hypotension and sensitivity to accelerations as is found with Bethanidine.

#### Theoretical advantages of Betablockade

The use of these drugs in the treatment of hypertension in aircrew has always looked attractive for a number of reasons:-

- a. They are effective hypotensive drugs.
- b. They produce a significant reduction of cardiac response to both physical and emotional stresses and markedly reduce the systolic peaks of blood pressure now thought to be one of the more dangerous features of essential hypertension.
- c. Most of these drugs have antidysrhythmic effects on the heart, particularly in preventing the occurrence of arrhythmias produced by catecholamines.
- d. The fall in blood pressure is not produced by posture or orthostatic effects.
- e. Occasional missed doses are not attended by an immediate rebound of blood pressure.

These factors seemed to comprise a number of highly desirable features for the treatment of aircrew providing any drug effects were not serious. It is ironic that as with so many powerful medications the exact mechanism whereby betablockade produces its hypotensive effect is not known. Proven actions include:

- a. Slowing of the heart and reduction of cardiac output.
- b. Reduction of the renin-angiotension system responses.

Originally it was surmised that other actions might include central nervous system effects acting through the vasomotor control but this is now largely discounted by the development of beta-one specific drugs which do not cross the blood-brain barrier very easily. The possibility of aortic arch baroreceptors being 'reset' at a lower level as a result of the reduction of cardiac responses to stress remains unproven. In fact no single theory of the mechanism of betablockade fits all the observed data.

However betablocking agents work to reduce hypertension we need to consider these observed effects in relation to aircrew and flight safety.

- a. Sinus Bradycardia. This can be very worrying when at rest certain subjects can fall below 50 beats per minute. The risk of loss of consciousness from this cause seems quite remote in men whose pacemaker and conduction are normal.
- b. The hypotensive effect is usually quite moderate in mildly hypertensive patients and extreme hypotension is not reported in fit adults. Orthostatic effects are minimal or absent.
- c. The fall in maximum cardiac output by about 20% in the early stages of treatment might certainly appear to comprise a possible problem in emergency situations, but Lund Johansson has shown that after a year's treatment the maximum cardiac output returns towards normal due to some unknown method of adjustment.
- d. Bronchospasm and increased airways resistance are the result of blockade of beta-two adrenergic nerve endings. This may have the effect of unmasking previously occult asthmatics or spasm may arise de novo. The effect is most commonly seen with the older non specific betablockers such as Propranolol and usually quite early on in treatment. The more specific beta-one blockers reduce this risk but it needs testing for by peak flow measurements during treatment.
- e. There has been a good deal of discussion on hypoglycaemic sensitivity during betablockade. The effect is largely seen in diabetics and study of carbohydrate metabolism should be done in aircrew under treatment.
- f. Coldness of the extremities is a common nuisance which is presumed to be due to unopposed alpha adrenergic action. It may be unacceptable in certain aircrew roles, it is liable to unmask and greatly exacerbate any underlying tendency to Raynauds disease.

The more serious toxic effects of betablocking drugs have included skin rashes, the milder forms of dry eye syndrome and the most serious of the "practolol syndrome" including visual impairment and retroperitoneal fibrosis. The incidence of these effects have been very small and all the betablocking drugs have been most carefully monitored for the disabling effects since the withdrawal of Practolol in the UK and other countries. No similar long term toxications have been identified or are expected to occur.

#### The Problem of Central Nervous System Effects

The first widely used betablocking drug was Propranolol. This compound easily crosses the blood-brain barrier and a number of CNS effects were reported particularly in subjects taking large doses. They included:

- a. Drowsiness and depression.
- b. Sleep disturbance and vivid dreaming.
- c. Hallucinations.

As noted these phenomena were dose related and rarely seen with less than 120 mg daily and the serious symptom of visual hallucination was practically always associated with high doses exceeding 600 mg daily of Propranolol. Nevertheless they have serious implications for aviation medicine and would clearly require a very careful assessment. Added to these central effects is the fact that betablocking drugs are used therapeutically by psychiatrists. This is usually a method of using small doses to abolish the psychosomatic effects of anxiety such as tremor and tachycardia. By some feedback mechanism the removal of these psychosomatic symptoms seems to reduce the actual level of anxiety but the doubt has always remained whether the drugs are intrinsically anxiolytic. This has remained in the cases of Propranolol and Oxprenolol which have been used in large doses in the treatment of severe mental disorder such as schizophrenia but the newer drugs such as Atenolol, Acebutolol, and Metoprolol have been shown experimentally hardly to cross into the brain at all and there are few reports of any significant central effects. Nevertheless it was clear that before use in aircrew could be contemplated the possibility of actions compromising human performance must be investigated.

#### Investigations

Apart from the use of these drugs by psychiatrists the early literature on betablocking drugs contained little reference to their effect on human performance. Taggart (6) has shown apparent improvement in the performance of racing drivers and diminution of anxiety symptoms in parachutists and public speakers. Bryan and others had found betablockade produced increase in simple reaction time. Glaister (7) and his group at Farnborough used an intravenous dose of 0.2 mg Oxprenolol on 24 volunteers to test the effect of betablockade on tolerance to GZ accelerations. They were divided into 12 "novice" and 12 experienced subjects who were exposed to a series of accelerations in the human centrifuge. He found no significant reduction in G tolerance despite the marked lessening of the normal response to the stress by tachycardia. He considered this some indication that betablockade did not produce any significant postural effect but was concerned that he found a doubtfully significant loss of accuracy in a coordination task (pursuit rotor tracking) done on the subjects while betablocked. This was not confirmed by later studies by Turner (8). Green and Cooke at Farnborough used a more sophisticated tracking task of an adaptive type in which a computer assessed the performance of the subject every 30 seconds and adjusted the level of difficulty accordingly. Nine subjects taking 80 mg Oxprenolol showed no evidence of impairment of performance in a double blind trial compared with their performance on a placebo. The same subjects showed no change in performance with a battery of paper and pencil tests. The overall results from a number of investigators therefore suggested that ordinary therapeutic doses of betablocking drugs in normal human subjects did not produce any significant or predictable loss of observed performance as would say a dose of alcohol or a hypnotic.

Nicholson has been working on the effects of betablockade on animals. He uses a delayed differentiation test with monkeys trained to respond to a double light signal combining both accuracy in discerning the correct signal to obtain a food pellet and the ability to measure the total time taken to respond to the signal. His object was first to show the effect of very large doses of betablocking drugs given by intraperitoneal injection and then to compare the effects of different betablocking agents at comparative doses. In a series of papers (9, 10) he has shown the marked central nervous system impairment produced by large doses of Propranolol and the earlier comparatively lipophilic drugs. More recently he has shown that the hydrophilic beta-one specific drugs such as Atenolol and Acebutolol show virtually no detrimental effect on the performance of the monkeys at any of the experimental doses up to 25 mg/kg. This is presumably because of their chemical nature and lack of passage of the blood-brain barrier. He has designed further experimental protocols and performance tests for more work on human volunteer subjects which are now proceeding.

The sum of this work done to date would seem to indicate that betablockade does not produce any observed constant loss of performance except in very large doses of the non specific lipophilic earlier compounds such as Propranolol.

#### Present Conclusions

The results of this work have been considered very carefully in the UK by both the Civil Aviation Authority (CAA) and the RAF. It was quite clear that however much investigation and research was carried out that it would be impossible to prove that a particular drug is completely safe for prescription for aircrew. At the same time continuing investigation could increase our knowledge as to the formulation of the drug and limits of dosage which are least likely to produce detrimental effects and this effort will continue. Meanwhile the CAA in 1980 considered the advice of its Medical Advisory Panel that it might now be justifiable to prescribe betablockers for mild cases of hypertension in aircrew with certain safeguards. This practice is already allowed by waiver by certain nations. Civil commercial operations



provide special circumstances both in the high proportion of middle aged pilots liable to significant wastage from hypertension and in the predominantly multipilot crews which afford a margin of safety by training for sudden incapacity due to cardiovascular disease or any unexpected effect of betablockade therapy. Eventually it was agreed that with proper safeguards betablockade treatment would not be likely to produce effects dangerous to flight safety.

The main problem was the definition of those proper safeguards. This would begin with a careful clinical reassessment with particular reference to:

- a. Confirming the need for treatment.
- b. Checks for target organ damage and associated risk factors.
- c. Simple biochemical checks of renal function, serum uric acid and glucose levels.
- d. Check for normal ventilatory function.

Where the subject was deemed suitable for treatment the effect of diuretic therapy alone would first be tried. Betablockade would be offered to those who did not respond entirely satisfactorily to diuretic therapy alone and particularly those who showed wide labile swings of pressure and tachycardia under stress (such as that of medical examination). Betablockade would thus normally be added to preexisting diuretic therapy or could be used alone.

Betablocking drugs would be used for a trial period of 4-6 weeks whilst the pilot was grounded. During this time he would be assessed for both subjective and objective evidence of any symptoms produced by the drug as well as for satisfactory control of his blood pressure. The difficult aspect of such symptoms was recognised to be the clash between the individual's career motivation to deny symptoms and the common finding that any form of hypotensive therapy can produce subjective symptoms in those previously symptomless. During this phase it was agreed that tests of performance should be carried out. After much argument it was decided that simulator testing would be the only method acceptable to both aircrew and their employers and that they should satisfy the ordinary standards of technical performance.

When a pilot showed good control of blood pressure and adequate performance on the drug he should return to flying with a waiver making him unfit solo pilot operations but fit co-pilot or captain with a fully trained co-pilot. Further checks by training captains would continue in the usual manner.

The dosage of betablocking drugs was to be limited to agreed levels because of the established dose relationship of side effects. No betablocking drug was specifically excluded but the newer hydrophilic compounds were to be favoured. Follow up of the control of the pilots blood pressure would be carefully monitored by both medical examiners and consultants.

So far it is too early to relate any experience. We have comparatively few aircrew on treatment and it will be some time before we can determine if control is better and the advantages outweigh the extra effort and cost of the programme.

From the Service aviation standpoint we have scrutinised the CAA's safeguards very carefully. Unfortunately a number are extremely difficult to transpose to the military situation. The present situation in the RAF is that it is felt that hypertension requiring betablockade therapy makes pilots:

- a. Unfit fast jets.
- b. Unfit single pilot operations.
- c. Unfit Flying Instructor.

If the CAA protocol of management is used this would confine service pilots to very limited roles in multipilot transport and marine reconnaissance aircraft. Their fitness for multipilot helicopter operations has been considered but thought to be very doubtful because of the constraints imposed by the speed of takeover required to correct human failures at low altitude. As regards other aircrew, we have tested a few navigators in fast jets and have confirmed the apparent normality of their G tolerance when taking betablockers. But in general terms all the problems of employing aircrew on operational flying whilst taking therapeutic drugs are increased by a considerable margin over their civilian counterparts by the complexity of their tasks, the extra physical stresses, and the level of their workload. For the present we need to keep an open mind and collect as much experience as possible.

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## DISCUSSION

DR D ELCOMBE (CA)

You alluded to long-term follow-up of civilian pilots on beta-blockade. Are they also on thiazide diuretics?

SPEAKER

Treatment with thiazides is normally tried as an initial aid in suitable patients, beta-blockade is added if thiazide treatment is not successful. In some cases beta-blockade may be substituted for diuretics.

DR D ELCOMBE (CA)

In Canada we have found that the people who require thiazides and beta-blockade are the more resistant sub-group and more difficult, whereas subjects responsive to beta-blockade alone are given a waiver.

INFLUENCE OF  $\beta$ -BLOCKING ATENOLOL AND OTHER MEDICATION ON THE  
REACTION TIME OF THE VISUAL SYSTEM

by

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SUMMARY

Visual reaction time as a measure of vigilance and of the psychophysiological condition of subjects was determined after combined physical and mental stress to examine  $\beta$ -blocker influence. Using the technique of electrooculography 40 subjects aged  $25.7 \pm 6$  with a mean blood pressure of  $126/79$  mmHg were measured in a double-blind cross-over design after application of placebo or 50 mg of atenolol (TENORMIN) for 3 days. Visual reaction time was defined as the time between display of a peripheral light signal and the start of the eye movement that shifts the direction of gaze from the reference point to the stimulus. The results of the study show, that under these experimental conditions there is a positive effect of beta-blocker medication on vigilance. Findings of other authors are discussed. To prove the sensitivity of the test-method in a preliminary study, the effects of the well-described drugs fenetyllin-hydrochlorid, diazepam, oxazepam and alcohol on visual reaction time were investigated.

INTRODUCTION

There are few, if any, drugs, which are not of importance in relation to flying duty, and particularly to a pilot. It is the Flight Surgeon's responsibility to take the necessary steps to see that no one flies as an aircrew member while under medication which might impair flying efficiency.

When new drugs receive popular acclaim in various periodicals, it becomes necessary for the Flight Surgeon to make sure that flying personnel are thoroughly indoctrinated regarding these drugs. This is particularly true of new medications affecting the psychomotor and sensory functions.

Beta Adrenergic Blocking drugs were introduced into clinical medicine some 15 years ago. Originally their main use was in the treatment of cardiovascular diseases. They provided a significant advance in the management of hypertension, in certain cardiac arrhythmias, and in angina pectoris. More recently they have been found to have an important application in protecting various body organs and systems from the effects of excessive anxiety. They are being employed to improve performance in individuals exposed to anxiety-laden environmental situations (1).

Side-effects of  $\beta$ -blockers related to their peripheral actions have been reported and are widely recognized. Jefferson (2) has reviewed extensively the available data on the possible existence and role of central beta receptors. He stresses, that much work needs to be done, before a central effect of beta-blocking agents can be established.

In animal studies the question of whether beta blockers cause sedation or depression of motor behavior remains in dispute, and various workers have reported widely different findings (1).

In experiments on human volunteers many workers were not able to detect significant effects on several behavioral parameters (1).

The lack of firm and consistent data about the effects of beta blockers on human performance is unfortunate, for, with such a broad spectrum of usage, it is likely that drugs of this type will be given to some persons carrying out highly skilled and potentially hazardous tasks where any significant degree of CNS depression would be undesirable.

The inconsistent results of those investigations which have been carried out, reflect, in part, the difficulties and relative insensitivity of most performance testing methods in man. Using a particularly sensitive method, the goal of this study was to examine the effect of a therapeutic dose of atenolol of the newer types of beta-adrenergic blocking drugs on the reaction time of the visual system, which is a measure of the psychophysiological condition of the subject.

MATERIAL AND METHODS

3 healthy male volunteers were recruited for the first part of the study. They took part in experiments about the influences of the most commonly described drugs fenetyllin-hydrochlorid (CAPTAGON), diazepam (VALIUM), oxazepam (ADUMBRAN), and alcohol on visual reaction time, to prove the sensitivity of the testing methods.

In the main part of the study 40 healthy male volunteers, aged  $25.7 \pm 6$  years with a mean blood pressure of  $126/79$  mmHg, were measured in a double-blind cross-over design to evaluate the effects of beta-blocking atenolol (TENORMIN) on visual reaction time after combined mental and physical workload.

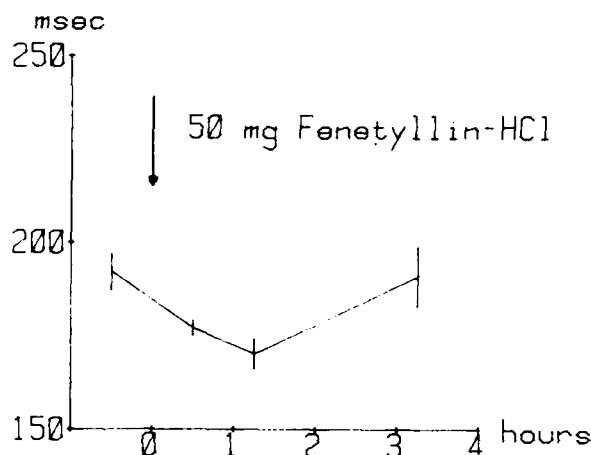
Visual reaction time was defined as the time between display of a peripheral light signal of  $10^\circ$  or  $20^\circ$  eccentricity and the start of an eye movement that shifts the direction of gaze from the reference point to the stimulus. Subjects had to look into the hooded window of a display, in which at a viewing distance of 1.40 m arranged by means of a lens system small red light signals are displayed  $20^\circ$  or  $10^\circ$  right or left from a reference point in the middle of the visual field. Lighting of an eccentric signal starts a digital clock with a precision of 1 msec. The clock is stopped via Schmitt-trigger when a critical corneo-retinal potential change, which is proportional to change of gaze, is reached. Corneo-retinal potential is derived from three electrodes placed to the carefully prepared skin of the subject at the outer canthi of the right and left eye respectively and over the bridge of the nose. One trial consists of 60 eye jumps to targets presented randomly at  $20^\circ$  or  $10^\circ$ , right or left from the middle of the visual field.

For the first part of the study mean and standard deviation of each trial was calculated for further statistical analysis.

For the main part of the study the median and interquartile differences have been calculated for further statistical evaluation in a two-period change-over design introduced by J.E. GRIZZLE (3). Mental workload was introduced by having the subjects calculate additions and subtractions for 24 minutes in a mechanical test equipment. Before mental workload, physical workload was employed by having the subjects on a Dynavit-training ergometer for 10 minutes, so that their heart rate was at the individual training frequency, which is automatically calculated by the training device.

#### RESULTS

The first part of experiments was done to prove the sensitivity of the measurement of visual reaction time to effects of well-known drugs. The first experiment was done with the caffeine-derivate fenetyllin-hydrochlorid. Fenetyllin-hydrochlorid is known to have a stimulating effect on the CNS. In Fig. 1 the effect of fenetyllin-hydrochlorid on visual reaction time is demonstrated.



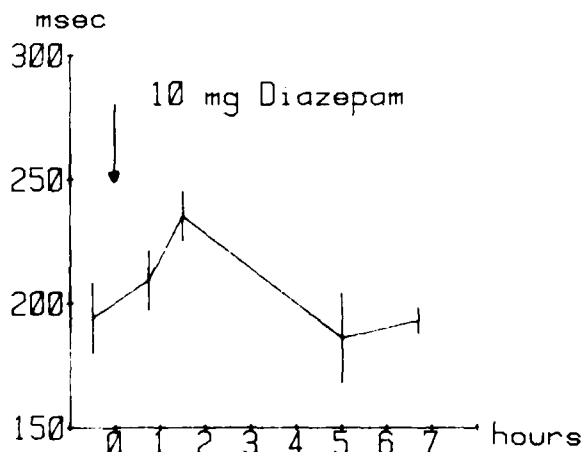
**Fig. 1**

Effect of fenetyllin-hydrochlorid on visual reaction time

(N = 22 per point)

30 minutes after ingestion of 50 mg of fenetyllin-hydrochlorid - the therapeutical dose - visual reaction time declines from a 200 msec starting value to 175 msec and reaches a minimum after 60 minutes at 170 msec. 210 minutes after ingestion of the therapeutical dose visual reaction time is back to normal.

In the second experiment the effects of the well-known sedative diazepam on the visual reaction time were studied. In Fig. 2 the reaction time of the visual system is about 200 msec around 30 minutes before ingestion of 10 mg of diazepam, a relative high therapeutical dosis. After 45 minutes a slight but significant increase to a reaction time of 210 msec is measured. About 100 minutes after ingestion of the drug the reaction time of the visual system has increased for about 20% to a value around 235 msec. After 5 hours, including a three hour's sleep period the reaction time of the visual system is back to starting values.



**Fig. 2**

Effect of diazepam on visual reaction time

(N = 1080 per point)

In the third experiment 10 mg of oxazepam, which is a sedative too, was given to the subjects. There were no effects on reaction time of visual system in the measurements 60, 120 and 320 minutes after ingestion of the therapeutical dose of this sedative in the normal experimental design.

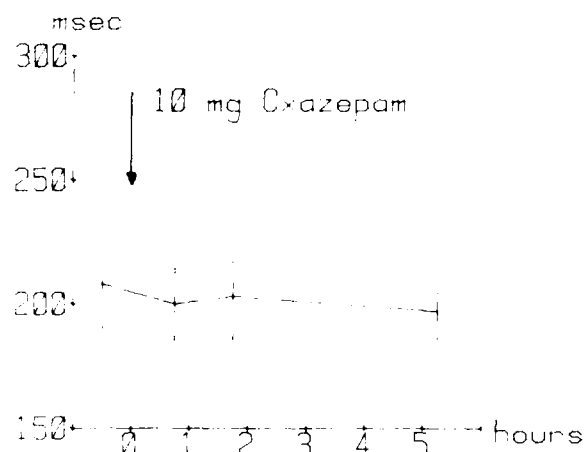


Fig. 3

Effect of oxazepam on visual reaction time.

(N = 240 per point)

However, when the subjects in a different experimental design were measured continuously for three consecutive trials after ingestion of 10 mg oxazepam - making the experiment itself a concentration task -, there was a significant increase in reaction time of the visual system.

Third, the reaction time of the visual system was studied on subjects, who had ingested 4 portions of 50 cm<sup>3</sup> of a 42 % alcoholic drink within 2 hours. After a start of reaction time at 200 msec, ingestion of the first portion of alcoholic drink decreased reaction time insignificantly. Increase in reaction time was found in the measurements 2 hours after ingestion of the first drink. Reaction times were still increasing up to 5 hours after ingestion of the first drink, that is three hours after the last drink.

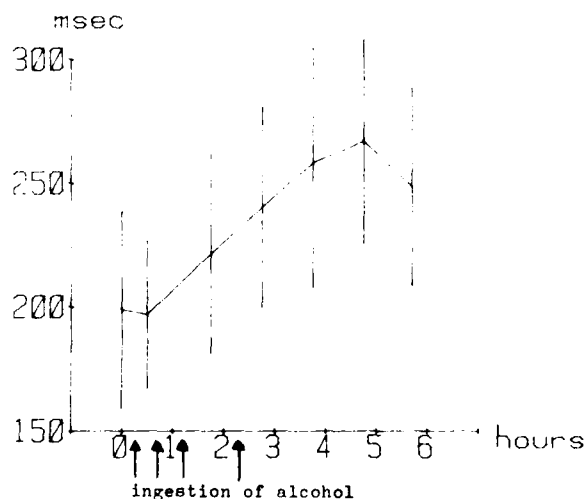


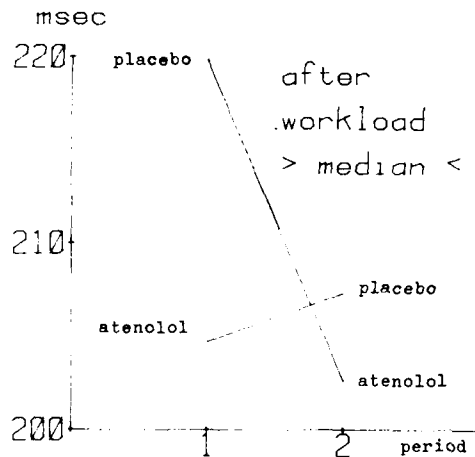
Fig. 4

Effect of alcohol on visual reaction time.

(N = 240 per point)

In the main study the 40 subjects were randomly divided into two groups. The first group starts with a three day's treatment A, e.g. atenolol 50 mg daily; the second group starts with a three day's treatment B, e.g. 1 x placebo daily. After a washout period of 2 weeks the first group was given treatment B and the second group treatment A. Measurements were done before the combined

mental and physical workload and afterwards. Blood pressure and heart rate changed as expected. There were no significant effects of treatment before workload for the medians of visual reaction time ( $p = 0.691$ ) as well as for the interquartile differences ( $p = 0.8085$ ). Visual reaction times after combined physical and mental workload are shown in Fig. 5. In both groups the visual reaction time is higher under placebo treatment as compared to treatment with atenolol.

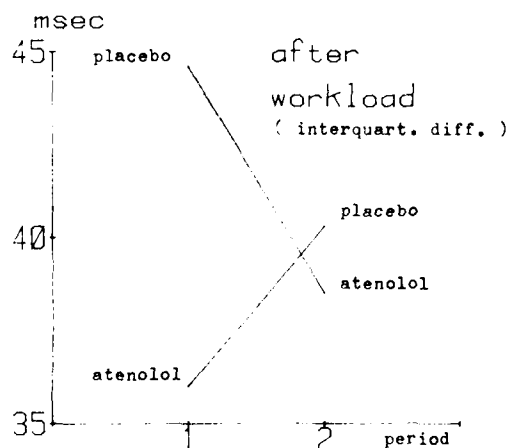


**Fig. 5**

Effects of atenolol and placebo on visual reaction time after combined workload

(N = 2400 per point)

The effects of the different treatments are the same with the interquartile differences, as shown in Fig. 6. Interquartile differences in both groups are higher under treatment with placebo as compared to treatment with atenolol. The effects of treatment after workload are highly significant for the medians of visual reaction time ( $p = 0.00393$ ) and significant for the interquartile differences ( $p = 0.0166$ ).



**Fig. 6**

Effects of atenolol and placebo on the interquartile differences of visual reaction time distribution after workload.

(N = 2400 per point)

Carry-over effects could be excluded for all variables.

The time effects after workload ( $p = 0.0265$ ) are due to training effects, for at this time subjects had to do the programs of physical and mental workload for the fourth time. The difference in medians of the placebo phase is due to training effects, too.

#### DISCUSSION

This study demonstrates that the reaction time of the visual system, described in literature as reaction time of saccadic eye movements (4), is sensitive to certain drugs. Fenetyllin-hydrochlorid which is known as a stimulant decreases the visual reaction time. The sedative diazepam increases reaction time, the sedative oxazepam showed no effect at the first glance, but with longer duration

of the experiment itself, there was an increasing effect, too. Alcohol showed a pronounced increase of reaction time after an insignificant but distinct decrease in the first phase. All the drugs investigated in this part of the study showed the effects that were expected.

Atenolol, a beta-adrenergic blocking drug, showed no significant effect on reaction time of the visual system before the combined mental and physical workload. After this workload there was a highly significant decrease of visual reaction time and a significant decrease of inter-quartile differences as compared to placebo measurements. These findings are in contrast to findings of several other authors working on beta-blockers. BROADHURST demonstrates that the beta-adrenergic blocking propranolol does cause a small but significant impairment of psychomotor functions. He states that these findings may have important relevance of the clinical situation, for patients taking beta-blocking drugs may well include individuals who are carrying out skilled tasks with dangerous potentials, such as operation of vehicles or machinery. Military and airline pilots certainly fall into this category, but their intake of drugs for any purpose is strictly regulated. According to BROADHURST (1) mild hypertension will not necessarily preclude from professional flying, but there is a controversy in aviation medicine circles as to what medication, if any, should be permitted for its treatment. At least one major airline is now accepting the use of beta-blockers (1) in its pilots, although no flying duties are undertaken for some months after starting treatment until haemodynamic stabilization is likely to have occurred.

The method of testing described produces only one measure of psychomotor performance, and does not distinguish between decrements of functions that might be of other central or peripheral origin. Nevertheless, it has been proved (4) that measuring the latencies of saccadic eye movements, the reaction time of the visual system, gives a sensitive and very stable measure of the psychophysiological condition of the subject.

However, it should not be inferred from the experiments described in this paper that the effect of atenolol upon psychomotor functions is shared by all other beta-blocking drugs. Propranolol as described by BROADHURST (1) causes a small but significant impairment of psychomotor functions and propranolol crosses the blood brain barrier more easily than several other beta-blocking agents studied (5). Penetration of these drugs into the CNS correlates significantly with their anti-hypertensive potency (5). It is possible that a similar relationship exists between the penetrative properties of different beta-blockers and their effect upon psychomotor functions (1). This may explain the different results that have been published in literature. The modern, less penetrative  $\beta$ -blocking betadrenol shows a shorter reaction time after ingestion (6, 7) just as atenolol in our study. The easy penetrating propranolol shows an impairment of reaction time (1).

Before inaugurating regulations for treatment of mild hypertension in aircrew with beta-blocking drugs more investigations about central effect of this type of drugs are necessary.

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Considerations on Long-Term Therapy of Hypertonia, Lipometabolic Disorders and Struma in Flying Personnel

by

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# SUMMARY

In our opinion, long-term drug therapy in flying personnel is only necessary in very few instances, as illustrated in cases involving hypertension, hyperlipoproteinemia (HLP) and euthyroid struma in our pilot population. We consider sound medical advice and guidance in cases of hypertension and HLP more important than drug therapy. Long-term treatment of euthyroid struma with thyroid hormones is only practical in rare cases.

# INTRODUCTION

All Federal Armed Forces pilots up to the age of 41 years are examined for military flying fitness every three years and thereafter yearly at the German Air Force Institute of Aviation Medicine (GAF IAM).

The number of follow-up examinations within a period of one year, i.e. from May 1st, 1979 to April 30th, 1980, totaled 1975 pilots of all age groups, of whom 796 were jet pilots, 311 propeller pilots and 868 helicopter pilots (Fig. 1).

**Flight physicals, rated pilots,  
1.5.79 - 30.4.80 (Total 1975)**

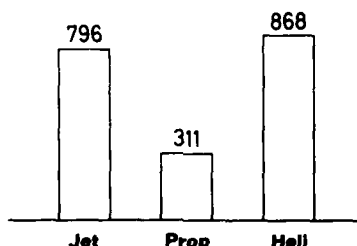


Fig. 1

The time period May 1st, 1979 to April 30th, 1980 was chosen as a basis for our studies, as all results of the flying fitness examinations at the GAF IAM have been stored in a data bank since May 1st, 1979. This type of documentation now enables us to carry out statistical evaluations. Thus, for example, we can determine the frequency of particular pathological findings within certain time periods. We have evaluated the findings of the pilots examined within this one year period, in order to investigate the problem of a practical drug therapy in flying personnel with regard to hypertension, HLP and euthyroid struma.

# PROBLEMS OF HYPERTENSION DRUG THERAPY IN FLYING PERSONNEL

According to WHO definitions (Fig. 2), hypertension was diagnosed in 169 of a total of 1975 pilots. In the majority of cases the diagnosis was borderline hypertension resp. mild manifest hypertension per se, predominantly type I. There wasn't a single case of secondary hypertension. At this point it must be noted, that only 7 of the 169 hypertensives were undergoing drug therapy (Fig. 3). As a result of the medical examination, drug therapy had to be re-instituted in one case only. Within the last 2 years, no pilot was suspended from flying duty because of hypertension alone. 82 (= 48.5%) hypertensive pilots had normal weight, 71 (= 42.0%) hypertensives were overweight (exceeded the Broca-Index by at least 5 kg) and in addition to overweight, 16 hypertensives (= 9.5%) had secondary metabolic disorders i.e. mild HLP or hyperuricemia (Fig. 4).



### Definition of Hypertonia

160/95	Hypertonia	21.3/12.7
140/90	Borderline-Hypertonia	18.7/12.0
	normal	
mm Hg		kPa

Fig. 2

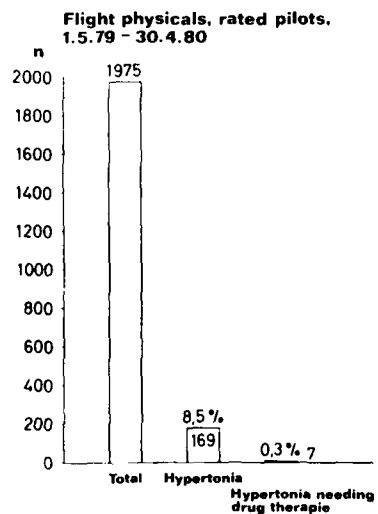


Fig. 3

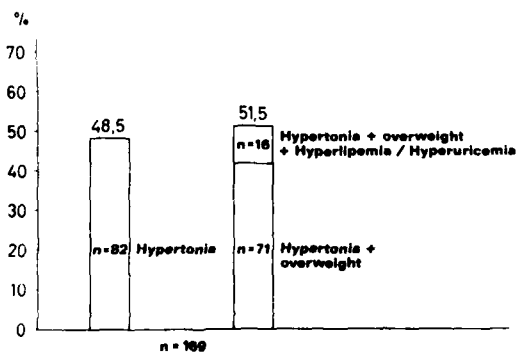


Fig. 4

We have divided the groups of normal and overweight hypertensives according to type of aircraft flown (jet, prop, helicopter) and age groups. The age groups are as follows: Up to the age of 30 years, between 31 and 41 years (41 years is a special age limit for the inactivation of jet pilots and jet navigators) and over 41 years of age.

A breakdown of the 82 cases, which as a rule involved mild hypertension without overweight, reveals no essential differences as far as age classification is concerned. If in addition, one considers the type of aircraft flown, there is a predominance of hypertension in young jet, middle-aged prop and older helicopter pilots (Fig. 5).

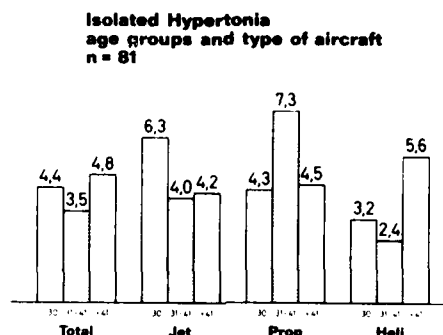


Fig. 5

A breakdown of overweight hypertensives applying the same criteria, however, shows a significant increase of hypertension with increasing age, in particular over 41 years in jet, prop and helicopter pilots alike. This supports the findings of Kirchhoff in 1971 regarding frequency, degree and cause of hypertension in flying personnel of the Federal Armed Forces (Fig. 6).

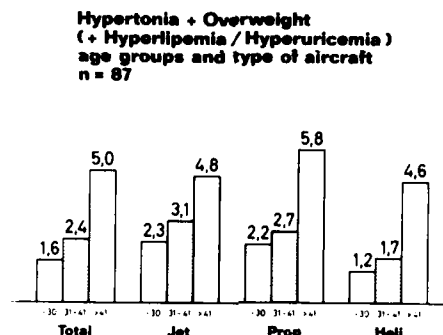


Fig. 6

The majority of pilots with high blood pressure had a so-called borderline hypertension. In this group the danger of a manifest hypertension is increased, however, the risk of a secondary disease (in relation to the total number of borderline hypertension cases) is relatively low. Therefore, at the present time, there are differences of opinion as to whether these persons require more comprehensive diagnostics of hypertension and to what extent drug therapy is necessary.

How then do we proceed in determining borderline hypertension?

Upon detecting a borderline hypertensive for the very first time, the flight surgeon is requested to record several daily blood pressure curves. A family case history is needed, since in borderline hypertensives there is frequently history of hypertension in the family. Moreover, a hereditary predisposition is considered to have a highly significant predictive value.

The physical examinations are aimed at covering two important points:

1. Detection of metabolic risk factors such as blood sugar, cholesterol, triglycerides and uric acid.
2. Detection of secondary causes of hypertension (nephrogenic, endocrine), as well as damage to hypertension prone organs. Because of the well-known frequent and close correlation between the clinical progress of hypertension and changes in the eye fundus, funduscopic examinations are part of the basic diagnostics at the GAF IAM. This comprehensive examination spectrum in cases of borderline hypertensives fully meets the requirements of the German League for Combating High Blood Pressure in diagnosing manifest hypertension.

Although we demand and carry out a maximum program in diagnostics, it seems reasonable - based on previous epidemiological knowledge in most pilots with borderline hypertension - to confine ourselves to the basic therapy important for hypertension of all degrees:

- weight reduction in conformance with Broca-Index
- sodium restriction: a moderate reduction of sodium intake to 5 - 6 gr daily will lower blood pressure. It is sufficient if the borderline hypertensive doesn't add salt to meals.
- regular physical conditioning (running, swimming, cycling)
- no smoking, reduction of beverages containing caffeine (recommended).

Because these so-called psycho-hygienic measures are often difficult to carry out in the flying unit under everyday conditions, we are very generous in recommending so-called fitness courses as a first step in the therapeutic basic program. In many cases however, it is not possible for us to carry out this basic program and at the same time keep up flying operations, due to lack of co-operation on the part of the pilots. In such cases we ground pilots temporarily, in order to force the start of therapy.

In 1974 King and his colleagues reviewed granted waivers and noticed that of approximately 6,500 waivers for flying personnel, hypertension was listed as a diagnosis for 754. Of these, 520 were pilots, of whom 268 i.e. over half were receiving drug therapy. Contrary to this, only 7 (4.19%) of our 169 hypertensives, mostly mild forms, required drug therapy. 6 of these were between 41 and 58 years of age. The only younger one was 32. All 7 had been granted a waiver, however only for prop and helicopter with dual controls and a second pilot. We feel if no drug therapy is necessary, pilots with borderline hypertension and those with a mild form of manifest hypertension (type I according to WHO) do not need a waiver.

The small number of hypertensives requiring drug therapy can be attributed to our thorough basic diagnostics and basic therapy. Blood pressure curves and application of basic therapy are supervised by the local flight surgeons, who are responsible for regular reports to the Institute. If deadlines are not met, reminders are automatically provided by the computer.

When deliberating if and by what means a drug therapy should be instituted, several aspects must be considered:

- the initiation of pharmacotherapy implies a life-long therapy with definitely negative psychological effects on the pilot.
- often in case of borderline hypertension and light manifest hypertension, an antihypertensive pharmacotherapy with normal dosage causes only a slight decrease in blood pressure, but at the same time very often has undesirable side-effects.
- pharmacotherapy is an individual therapy, which is possible because of our small number of cases. With regard to flying personnel, all drugs, with the exception of diuretics and possibly beta-blockers, are excluded to begin with, due to the undesirable side-effects; in particular reaction impairment and orthostatic instability. Pilots of the Federal Armed Forces have only been treated with hypertensive drugs since 1975. Initially only the potassium-saving diuretics were used. A combination of 50 mg triamterene and 25 mg hydrochlorothiazide is preferred. 4 1/2 years is the longest period this drug was known to have been tolerated with no significant undesirable side-effects and with adequate lowering of blood pressure.
- In one case increased fatigue was an undesirable side-effect during this therapy. In another case involving an individual having ideal body weight, therapy had to be changed to beta-blocker because of pronounced dehydration symptoms (over-dose).
- The above mentioned 32 year old helicopter pilot with severe hypertension while under stress and subjective complaints (often headaches) has been treated successfully with Propanolol-HCl for 18 months.
- A 50 year old helicopter pilot with additional accumulated ventricular extrasystoles has been under a monotherapy with a beta-blocker for one year without undesirable side-effects. Mention should also be made of a 55 year old commander in whom we were unable to achieve adequate decrease of blood pressure by way of a monotherapy either with diuretics or beta-blockers. With a combination of potassium-saving diuretics and a beta-blocker however, he has been showing satisfactory blood pressure values for one year. (At this age, a lowering of blood pressure below 140/90 is not desirable).

We do not intend to permit a drug for general use in the treatment of hypertension in flying personnel. Potassium-saving diuretics resp. beta-blockers may only be prescribed individually with the consent of the GAF IAM (waiver). We have only had experience with 4 different beta-blockers due to our limited number of cases. Further application of so-called cardio-selective beta-blockers for treatment of hypertension is not yet planned, pending further clarification of therapeutic mechanisms.

#### PROBLEMS OF HYPERLIPOPROTEINEMIA (HLP) DRUG THERAPY IN FLYING PERSONNEL

The importance of HLP as a risk factor in atherosclerosis has been reviewed in several ways within the last few years. The fact that certain forms of essential HLP (particularly hereditary elevated cholesterol levels) present an atherogenic risk of the first order is still indisputable. These forms of HLP are, however, extremely rare. Due to the fact that lipid determinations by initial examinations for flying fitness at the GAF IAM have been carried out for more than 10 years, and candidates with essential HLP are not admitted to flying training, we are not confronted with the question of long-term treatment of these metabolic disorders.

Moreover, we are aware of the problem, that dietary measures as well as differentiated drug therapy will not change the serum level to any great extent. On the other hand, dietary treatment alone can bring about astonishing changes in the serum lipids in secondary HLPs, especially if the HLP is of a predominantly elementary nature. At this time we should like to mention the case of a

pilot who was examined 7 years ago in a well-known clinic and was found to have essential hypercholesterolemia with values of about 420 mg/dl. After not having drug therapy for more than 5 years, his serum cholesterol level is 180 mg/dl. It is our opinion, that he simply had a symptomatic secondary HLP.

These forms of HLP (cholesterol 260 mg/dl, triglycerides 228 mg/dl) are just as frequent in flying personnel of the German Armed Forces as in a non-selected population (Fig. 7 and 8). Comparative study results have already been reported in 1974 by Jung from the GAF IAM. There being no better theory for the development or promotion of premature degenerative cardiovascular diseases than the theory of risk factors, we make every effort to eliminate these factors in our flying personnel. However, we don't go as far as treating secondary HLP with drugs, even if dietary measures should be unsuccessful, since in most cases we are dealing with mild forms of secondary HLP.

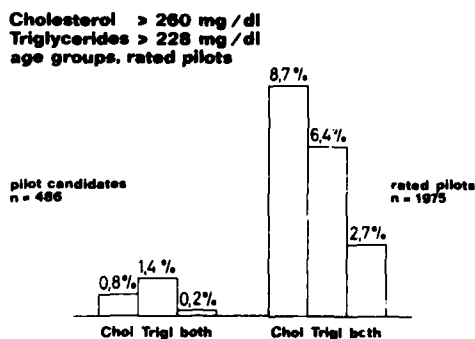


Fig. 7

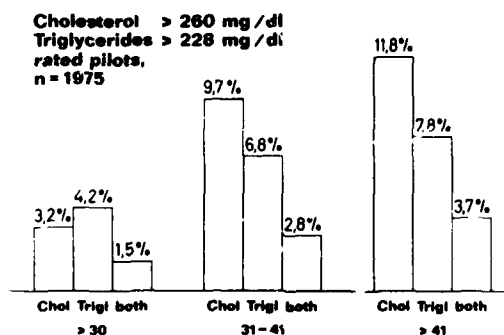


Fig. 8

Physical exercise adapted to the individual performance ability is always called for in conventional therapy of these secondary lipometabolic disorders. This has a favourable influence on the high density lipoproteins (HDL) / low density lipoproteins (LDL) - cholesterol quotient known to promote atherosclerosis. Done the way it should be, this physical exercise is not only inexpensive, but without risks and accepted by most pilots.

Reasonable nutrition is, however, not so readily accepted in cases of dietary treatment of HLP. In plain language, all it means is reduction of overweight, reduction of alcohol consumption, reduction of carbohydrates and lipids in total calories. It is very difficult to carry out more differentiated dietary treatment under everyday conditions.

Considering that vegetarians have an unfavourably low HDL-cholesterol level and achieve a more favourable atherogenic protective factor only through formation of the quotient HDL/LDL-cholesterol, the difficulty in understanding the role of the lipids as pathogenetic factors of atherosclerosis is illustrated.

Disregarding the public controversy about which is better, butter or margarine, drug therapy of HLP has become a major issue in the health policy of the Federal Republic.

At the beginning of 1979 Clofibrat was prohibited by the Federal Health Authorities. In August 1979 Clofibrat was again released, with severe restrictions, for the treatment of serious primary lipometabolic disorders together with elevated triglycerides and cholesterol levels, as well as for treatment of serious secondary hypertriglyceridemias. This applied only to such cases where neither a change in nutrition nor in habits was successful. The pharmaceutical companies were compelled to include the following notice in the instructions for use of Clofibrat:

" .... so far it has not been proven, that a lowering of elevated lipids will prevent or improve atherosclerosis or resulting diseases, e.g. coronary heart disease or vascular diseases with subsequent circulatory disorders of the extremities or brain". The instructions continue by mentioning a long-term study on patients suffering from cardiac infarction which shows, that treatment with Clofibrat induced a higher rate of side-effects such as angina pectoris, claudicatio intermittens, thrombo-embolism and cardiac arrhythmias than in a control group. Further, another extensive long-term study is mentioned, which was carried out on individuals with healthy hearts and elevated cholesterol levels averaging 250 mg/dl, who received Clofibrat for more than 5 years. In this group the mortality was one-third higher than in a control group. It could not, however, be proven beyond doubt, that Clofibrat caused a larger number of cancer cases. Since spring 1980, there is separate doctor and patient information, and the foregoing is included only in information for the doctor in order to improve patient compliance.

#### PROBLEMS OF EUTHYROID STRUMA DRUG THERAPY IN FLYING PERSONNEL

The euthyroid struma is the most common of all thyroid disorders. It is an enlarged, non-hyperthyroid thyroid gland, showing no signs of being inflamed or malignant. In the Federal Republic struma appears endemically in certain geographical areas (Fig. 9). The size classification of the euthyroid struma corresponds with the recommendations of WHO (Fig. 10). For detailed therapeutic and prognostic reasons, subdivisions into diffuse or nodular struma is also of clinical importance. Lack of iodine in food and water is the most prominent etiological factor in the growth of struma. A combination of several unfavourable circumstances results in the manifestation of euthyroid struma. All factors causing euthyroid struma lead to the same pathogenetically decisive condition of a reduced incretion of L-thyroxine and triiodothyronine. This reduction in the concentration of thyroid hormones in serum causes an increased secretion of thyroid stimulating hormone (TSH) by the anterior lobe of the pituitary gland via the negative feed-back mechanism. This increased TSH-stimulant causes various biochemical changes in the thyroid gland and stimulates growth of thyroid tissue. Based on this etiopathogenetic knowledge, long-term therapy of euthyroid struma with thyroid hormones has been practiced on a wide basis in the last few years (Fig. 11).

Incidence (%) of struma in  
draftees born 1937 - 1952  
(F.A. Horster et al.)

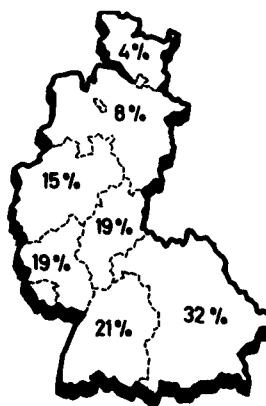


Fig. 9

## Types of euthyroid struma following WHO

Type 0	no struma
I	palpable struma
II	visible struma (normal position of head)
III	large struma

Fig. 10

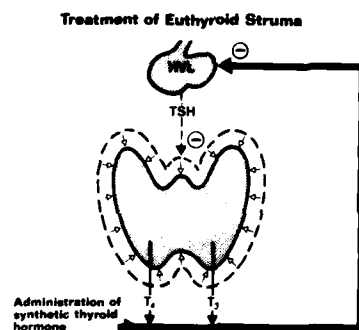


Fig. 11

Between 1975 and 1977 pilots and pilot candidates at the GAF IAM having an euthyroid struma were systematically treated with thyroxine, following diagnosis by means of thyroid scintigraphy, T<sub>3</sub>-T<sub>4</sub> determination in serum and if necessary X-rax of the trachea. Between May 1st, 1979 and April 30th, 1980, 27 pilots were re-examined to see whether treatment with thyroxine (50 micrograms - 100 micrograms daily) had been successful. This treatment was applied for a period of 2 months to 4 years. The patients themselves noticed no change in the thyroid gland; visual examination and palpation revealed no changes (as far as comparable because of different examiners). In no case were there noticeable changes in neck circumference. It is well-known, that changes in thyroid volumes, even though objectively determined, will not effect neck circumference. Thyroid scintigraphy as primary parameter and accurate indicator for changes in the thyroid gland was available in only 10 of 27 cases.

Our results are contrary to the findings published recently by Hengst and Fasshauer. They treated 221 young males for an average of 14 months with thyroid hormones (100 - 150 micrograms daily) in order to reduce the volume of the euthyroid struma. In 90% there was a therapeutical effect, in 46% there was a pronounced reduction in thyroid volume, and in 10% struma increased during treatment. The authors reported no essential difference as to the effectiveness of thyroxine in comparison with a thyroxine-triiodothyronine combination.

Our patients were treated with thyroxine exclusively in order to avoid unphysiologically high "T<sub>3</sub>-peaks". In only one case were undesirable side-effects (restlessness, moist hands, etc.) noticed after taking 50 micrograms thyroxine daily.

According to our findings, the problems of euthyroid struma drug therapy in flying personnel are manifold: pilots are reluctant to take the prescribed thyroid hormone dosage regularly, since nearly all cases are asymptomatic. During the first stage with step-wise increase of thyroid hormone dosage, pilots must be grounded for at least 4 weeks, realizing that the grounding period is in no proportion to the nature and seriousness of an euthyroid struma (Fig. 12). The optimal suppression dosage must be determined under treatment by the TRH-Test (thyrotropin releasing hormone). According to latest studies, the extent of the suppression of the TSH serum level by TRH serves as the most important indicator for the effectiveness of the initiated thyroid hormone treatment. According to these criteria, we assume our pilots had not received adequate therapy (Fig. 13 and 14).

Taking the fact, that no struma increased in size while under treatment as a criterion for therapeutic success, we were 100% successful.

Past experience shows euthyroid struma to be simply a relative indication for further diagnostic steps. A long-term therapy (at least 2 years) with thyroid hormones, taken regularly and in optimal dosage, should only be instituted in the presence of signs and symptoms such as narrowing of the trachea or dysphagia.

#### Schedule of Therapy with L-Thyroxine

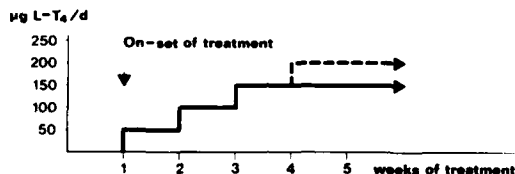


Fig. 12

#### Schedule of Therapy with L-Thyroxine

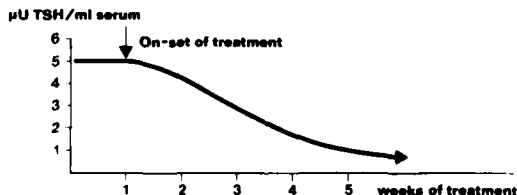


Fig. 13

#### Schedule of Therapy with L-Thyroxine

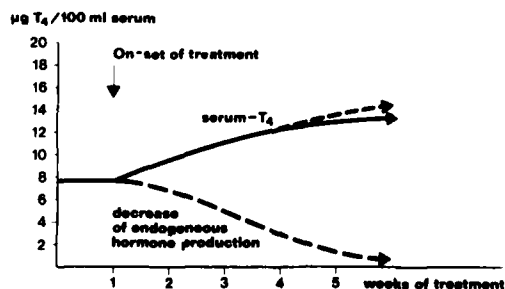


Fig. 14

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14. Abstract

The introduction of advanced aircraft has placed a much increased stress on aircrew who are subjected to the high physical stress loads of sustained high 'g' manoeuvres, vibration, high noise levels and heat stress. Crews are required to produce a constant high degree of concentration with little or no margin for error. Is an increased degree of aircrew fitness necessary? Is there a need for special selection of the crews to fly these aircraft?

The diagnosis of certain diseases has, to date, resulted in the concerned aircrew being declared permanently unfit to fly. Modern methods of treatment, however, have now made it possible to consider the return of these aircrew to flying duties. Under what conditions may aircrew with diseases which require long-term therapy continue to fly and what limitations must be applied in such cases?

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